Lake Michigan Pilot Study

of the

National Monitoring Network for U.S. Coastal Waters and Their Tributaries

A project of the

Lake Michigan Monitoring Coordination Council
and many Lake Michigan and Great Lakes partners

for the

National Water Quality Monitoring Network

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Lake Michigan Monitoring Coordination Council

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Introduction

Lake Michigan was selected as one of three pilot studies across the nation to test and improve upon the design of the National Monitoring Network for U.S. Coastal Waters and Their Tributaries (NMN). The other two pilot studies were Delaware River and San Francisco Bay. This report provides background information, discusses management issues, an inventory of monitoring under resource components of the NMN, a gap analysis and projected costs to implement the NMN for Lake Michigan.

The Great Lakes and Lake Michigan in particular, are in a period of changing conditions due to a wide spectrum of watershed stressors from toxic pollutants, nonpoint source pollution and water level fluctuations to invasive species disrupting the food web and ecosystem and rampant developmental pressures throughout the region. Thus unique needs exist in the region, however consistent monitoring and assessment approaches with other regions of the nation may be necessary to address these issues under a common framework. The NMN may find that a set of expressed site-specific needs and gaps for Lake Michigan might actually be common needs in other coastal regions.

With these issues at the forefront, partners working on or around Lake Michigan – including federal and state agencies and academic institutions – have established a robust framework of research and collaborative monitoring efforts. The Lake Michigan Pilot Study enabled partners in the basin to better address these stressors and management issues. It also helped to point out the level to which Lake Michigan Lakewide Management Plan (LaMP)-expressed needs are being met. Results of the Study will serve as a catalyst for assessing and improving upon observing, monitoring and reporting needs for the above-mentioned and other rapidly emerging ecological problems both in the Lake Michigan basin and in the Great Lakes region. Moreover, the explicit linkage between upland, coastal and offshore waters necessitates a more coordinated monitoring network.

The Lake Michigan Pilot Study is also as an excellent surrogate for most coastal marine environments, with its focus on integrating observations of complex physical, chemical and biological processes and development of enhanced monitoring strategies. The Lake Michigan Pilot Study will ultimately generate a monitoring design that could be applied to the other four Great Lakes to better assess the ecological status of the entire Great Lakes basin, while complementary with monitoring parameters in other coastal regions of the United States through its cooperation in the National Monitoring Network for U.S. Coastal Waters and Their Tributaries.

I. Overview of the Study Area

Size and Characteristics of the Lake Michigan Watershed

The Great Lakes – Michigan, Huron, Superior, Erie and Ontario – are a dominant part of the physical and cultural heritage of North America. Shared with Canada and spanning more than 750 miles from east to west, these vast inland freshwater seas provide water for consumption, transportation, power, recreation and a host of other uses. The Great Lakes are the largest surface freshwater system on the Earth. They contain about 84 percent of North America's surface freshwater and about 21 percent of the world's supply. Only the polar ice caps contain more freshwater.

The Lake Michigan basin is the area of land where rivers and streams all drain into Lake Michigan. The lake discharges into Lake Huron through the Straits of Mackinac at a rate that allows for a complete change of water about every 100 years. Lake Michigan forms a link in a waterway system that reaches east to the Atlantic Ocean and south through the Mississippi River to the Gulf of Mexico. Among the large rivers that enter the lake are the Fox and the Menominee in northeast Wisconsin; the St. Joseph, the Kalamazoo, and the Grand in southwest Michigan. Lake Michigan is the sixth largest lake in the world and is the only Great Lake that lies entirely within the boundaries of the United States. The lake's drainage basin covers more than 45,000 square rules and

Map and Boundaries of the Lake Michigan Pilot Study Area in 8-Digit HUCs

Size Statistics (Lake Michigan)	
Length:	307 miles (494 meters)
Width:	118 miles (190 meters)
Land Drainage Area	45,600 square miles[i] (118,000 square kilometers)
Depth:	925 feet maximum depth (282 meters)
	279 feet average depth (85 meters)
Shoreline:	1,660 miles (2,633 kilometers) largely of sand & pebble beaches

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[i] Page 4, The Great Lakes An Environmental Atlas and Resource Book Third Edition (1995) Jointly produced by Government of Canada, Toronto, Ontario and United States Environmental Protection Agency Great Lakes National Program Office Chicago, Illinois.

drains parts of four states: Wisconsin, Illinois, Indiana, and Michigan. Its average depth is 279 feet, and its maximum depth is 925 feet.

Projections indicate that the built landscape surrounding southern Lake Michigan will grow between 400 and 700 square miles by 2025, an increase of nearly 40 percent. Further projections indicate that another two million people will live in and around southern Lake Michigan by 2030. Given that we already extract as much water from Lake Michigan as is allowed by international treaties, these projections suggest the Southern Lake Michigan region will face considerable water supply challenges in the coming decades.

The Lake Michigan Watershed

Major Tributaries

Lake Michigan has 33 tributary watersheds at the 8-digit hydrologic unit code (HUC) and 22 at the 6-digit HUC[ii] as defined by the U.S. Geological Survey (USGS). Most of these watersheds are impaired due to contaminated sediments that have accumulated over the years of industrialization in the Midwest. These tributaries have also been impaired by the many dams that were installed in the past. A relatively recent focus on dam removals throughout the basin has begun to improve fish habitat, water quality and diversity of species.

Major Land and Resource Uses

Lake Michigan has unique conditions that support a wealth of biological diversity, including many plant and animal species found nowhere else in the world. Lake Michigan basin's sand dunes, coastal marshes, tall grass prairies, savannas, forests, and fens all provide essential habitats for this diversity of life. Agricultural and industrial products such as iron ore, coal, limestone, metals, petroleum, coke, and chemicals are derived from the basin's resources. The water of Lake Michigan serves many purposes. It supports large commercial and sport fishing industries. It provides industrial process and cooling water, and water for agricultural irrigation. Fleets of freighters pass over the Lake carrying bulk commerce items. Lake Michigan serves as a source of drinking water, as a place for swimming and fishing, as a scenic wonderland, and as a sink for municipal and industrial waste and runoff from the surrounding lands.

Basin Land Use:	Shoreline Use:
Agricultural, 44%	Agricultural, 20%
Residential, 9%	Residential, 39%
Forest, 41%	Recreational, 24%
Other, 6%	Commercial, 5%
	Other, 5%

Source: 2006 Lake Michigan Lakewide Management Plan

[ii] Table 3-4 on page 52 of A National Water Quality Monitoring Network for U.S. Coastal Waters and Their Tributaries says 22 with a footnote, "Does not include the 5 Accounting Units that are entirely a Great Lake." Page 56 of the Report also says that there are 22 HUC-6 basins. Appendix 3-4 of the Report lists Great Lakes Drainage River Monitoring Sites, including 17 for Lake Michigan.

II. Major Management Issues

The diverse geology, biology, land uses and water uses in the Lake Michigan basin contribute to the variety of management issues faced by stakeholders in the region. In 1972, both the United States and Canada recognized the importance of restoring and maintaining the chemical, physical and biological integrity of the Great Lakes with the signing of the Great Lakes Water Quality Agreement (GLWQA). A protocol was added to the GLCWC in 1987 to aid states and provinces in developing time tables for restoration activities, creating measures of accountability, and to endorse a coordinated, cooperative effort to protect and restore the Great Lakes ecosystem. The protocol emphasized both human and aquatic system health and directed the two countries to develop Lakewide Management Plans (LaMPs) for each of the Great Lakes. The LaMP describes goals and ecosystem objectives for the Lake Michigan Basin, as identified in the tables below.

These discussions and actions resulted in continued work on chemical stressors and a definition and framework for the LaMP ecosystem scope. This expanded scope encourages work on physical and biological stressors, human health, the continuation of activities to address beneficial use impairments, and the development of a set of LaMP objectives. The challenge of the LaMP is to coordinate the ecosystem goals and objectives with the GLWQA's beneficial use impairments and numerous other federal, state, tribal, and local goals to produce a clear, strategic action agenda.

In addition, the 1987 GLWQA amendment required the U.S. and Canada to identify Areas of Concern (AOCs), where the highest concentrations of pollutants in the Great Lakes were known to occur. Restoration of these areas was to be planned and implemented with the creation of Remedial Action Plans (RAPs) for each AOC. Fourteen beneficial uses of Great Lakes waters were identified, and RAPs identify those beneficial uses that have been impaired for each AOC and outline how each impairment will be addressed.

The 2000 Lake Michigan Lakewide Management Plan (LaMP) describes goals and ecosystem objectives for the Lake Michigan Basin. In 1998, the Lake Michigan Technical Coordination Committee (Federal and State LaMP partners) and the Lake Michigan Forum worked with the Green Mountain Institute for Environmental Democracy to develop goals and objectives for the LaMP using comparative risk methods. The goals build upon and amplify the *Revised Great Lakes Water Quality Agreement of 1978 as Amended by Protocol Signed November 18, 1987* (GLWQA), which documents the parties' purpose to restore the chemical, physical, and biological integrity of the Great Lakes Basin ecosystem. In 1997, the Lake Michigan Management Committee approved an ecosystem scope for the Stage 1 Lake Michigan LaMP, and in August 1998, the Management Committee adopted ecosystem goals. The challenge of the LaMP is to coordinate the ecosystem goals and objectives with the GLWQA's beneficial use impairments and numerous other federal, state, tribal, and local goals to produce a clear, strategic action agenda.

The Lake Michigan LaMP's ecosystem approach to restoring the chemical, physical, and biological integrity of the Great Lakes encourages the continuation of activities to address beneficial use impairments and the development of a set of LaMP objectives, goals, and subgoals. The challenge of the LaMP is to coordinate the ecosystem goals and objectives with the GLWQA's beneficial use impairments and numerous other federal, state, tribal, and local goals to produce a clear, strategic action agenda. Appendix 1 ("Relationship of Parameters from the National Monitoring Network to the Lake Michigan Lakewide Management Plan") shows how the National Water Quality Monitoring Network for U.S. Coastal Waters and Their Tributaries (NMN) (column 1) corresponds to the Lake Michigan LaMP endpoint goals (columns 2 through 6) and means to an end goals (columns 7 through 11). The Lake Michigan Pilot Study has identified the following as key management issues regarding the overall health of Lake Michigan and its watershed.

Management Issue: Fish Consumption Advisories

Issue: Commercial and sport fishing are important to a sustainable Lake Michigan. The need still exists for all four Lake Michigan states to maintain advisories to warn the public about potential health effects resulting from consuming certain species of sport fish in the lake as well as inland lakes. Lake Michigan fish advisories are due to PCBs, mercury, chlordane, DDT, and dioxin[iii] . Emerging chemicals should also be addressed.

Rachel Carson's 1962 book *Silent Spring*[iv] brought attention to various industrial and agricultural poisonings (e.g., PBB in Michigan animal feed) and raised national awareness of the risk of contamination to the nation's food supply. In the 1990s, the U.S. Food and Drug Administration (FDA) identified risk-based action levels for these contaminants in fish: Aldrin/Dieldrin; Benzene hexachloride; Chlordane; Chordecone; DDT, TDE, and DDE; Diquat; Fluoridone; Glyphosate; Arsenic; Cadmium; Chromium; Lead; Nickel; Methyl Mercury; Heptachlor/Heptachlor Epoxide; Mirex; Polychlorinated Biphenyls; Simazine; and, 2,4-D (on a limited basis). Furthermore, the United States Environmental Protection Agency (U.S. EPA) sets allowable pesticide residue concentrations, called tolerances, for additional pesticide active ingredients that may be in food. The U.S. EPA, FDA and states monitor for subsets of these contaminants, leaving some uncertainty as to the presence and synergistic effects of all the contaminants listed above[v]. Public health agencies in all four Lake Michigan states maintain advisories to inform the public about potential health effects resulting from consuming certain species of sport fish in the lake as well as inland lakes.

Contaminant monitoring data is essential to preparation of fish consumption advisories since States base fish consumption advisories on available data. The available data varies from state to state with respect to the frequency, number and contaminants reported. Within each State, fish contaminants are monitored for different subsets of contaminants because fish monitoring programs are funded from multiple sources which may be of limited duration or available only for a certain geographic area. Illinois and Indiana do not issue fish consumption advisories due to or monitor for dioxin in Lake Michigan fish, however they do monitor for select organics and metals. In Indiana, sampling and testing to support dioxin-based advisories for the Ohio River fishery is supported by the Ohio River Valley Sanitation Commission (ORSANCO). Mercury and PCBs are contaminants common to all four states.

[iii] These pollutants are identified from review of Illinois, Indiana, and Michigan's Clean Water Act section 303(d)/305(b) draft 2006 reports and Wisconsin's 2004 final report.

[iv] Carson, Rachel. *Silent Spring*; Houghton Mifflin Co.: Boston, MA, 1962.

[v] See Michigan's "State Fish Advisory" at www.michigan.gov/mdch/0,1607,7-132-2944_5327-13110--,00.html. Michigan Department of Environmental Quality's "Fish Contaminant Monitoring Program" is online at www.deq.state.mi.us/fcmp/. See Wisconsin's "Choose Wisely A Health Guide for Eating Fish in Wisconsin" online at http://dnr.wi.gov/fish/pages/consumption/Fish%20Advisory%2007%20web%20lo.pdf and Wisconsin's Department of Natural Resources "Water Division Monitoring Strategy" (7/25/2006) online at http://dnr.wi.gov/org/water/monitoring/MonitoringStrategyV2.pdf. See Illinois EPA's "Water Monitoring Strategy 2002-2006" at www.epa.state.il.us/water/water-quality/monitoring-strategy/2002-2006/monitoring-strategy-2002-2006.pdf and a response to the question, "Why are there so many new PCB advisories this year[2002]?" at www.dnr.state.il.us/fish/fishadvisoryfactsheet2002.htm and the Fishing Digest (includes consumption advice) at www.dnr.state.il.us/fish/digest/digest.pdf. See Indiana State Department of Health's "Indiana Fish Consumption Advisory" at www.in.gov/isdh/dataandstats/fish/2007/ and Indiana Department of Environmental Management's "Surface Water Quality Monitoring Strategy" at www.in.gov/idem/programs/water/quality/swqms2001findoc.pdf.

In 2003, the most recent year for which FDA interstate commerce fish and shellfish data are available on-line, 273 domestic samples of fish/shellfish and other aquatic products are reported for the nation. Whether or not any of these freshwater fish originated from the Great Lakes could not be determined from the references located during preparation of this report. Pesticide residue was found in 23.8% of the samples and not detected in 76.2% of the samples. Samples with detectable concentrations were below FDA violative concentrations. FDA analytes for freshwater nonaquaculture bass, carp, white catfish, smelt, trout, and drum included 152 pesticide residue targets, including Aldrin, Dieldrin, Chlordane, DDT, Heptachlor (total), Mirex, and Simazine. Lake Michigan Pilot Study partners have not been able to answer, for the Lake Michigan Watershed, whether FDA pesticide target analytes have been eliminated from monitoring programs because they were not detected or because analytical methods were not available (or for some other reason. The U.S. EPA Great Lakes National Program Office (GLNPO) has a long-standing Great Lakes fish Monitoring Program (GLFMP). Diagrams from the GLFMP show a relatively rapid decline in contaminants following new regulations in the 1970s and a much slower rate of reduction more recently.

Potential management options for this issue include:

- Providing federal funds for fish contaminant monitoring for FDA, EPA, and State contaminants in all four States to determine an appropriate subset of contaminants for routine monitoring.
- Use monitoring results for more than fish consumption advisories; what does presence of these contaminants tell us?
- Whether or not we can eat the fish depends on their presence, a function of food supply, competition from aquatic invasive species (AIS), and habitat changes, including those caused by AIS and factors like climate change.

Management Issue: Toxic Hot Spots – Great Lakes Areas of Concern

One of the major management issues in the region is the continued cleanup of Great Lakes Areas of Concern (AOC), the basin's most degraded waterways. The Lake Michigan basin contains 10 of these areas. They are defined by the U.S.-Canada Great Lakes Water Quality Agreement (Annex 2 of the 1987 Protocol) as "geographic areas that fail to meet the general or specific objectives of the agreement where such failure has caused or is likely to cause impairment of beneficial use of the area's ability to support aquatic life." The U.S. and Canadian governments originally identified 43 such areas; 26 in U.S. waters, 17 in Canadian water (five are shared between U.S. and Canada on connecting river systems). A few AOCs on both sides of the border have since been delisted. The GLWQA, as amended via the 1987 protocol, directs the two federal governments to cooperate with state and provincial governments to develop and implement Remedial Action Plans (RAP) for each AOC to address impairments and accelerate their cleanup.

Each AOC is stricken with a number of use impairments including, among others, degradation of benthos, restrictions on drinking water consumption, loss of fish and wildlife habitat, eutrophication or undesirable algae, beach closings, and restrictions on dredging activities. As part of the RAPs, restoration targets are being or have been developed to assess progress toward addressing these impairments. Monitoring evidence will document remediation of beneficial use impairments and will eventually support delisting each AOC. While routine state water quality monitoring meets some of these needs for evidence, benchmarks or criteria have not been developed for all the beneficial use impairments. The following waterways are designated as Lake Michigan AOCs:

- Manistique River
- Menominee River
- Fox River-Southern Green Bay
- Sheboygan River
- Milwaukee Estuary
- Waukegan Harbor
- Grand Calumet River
- Kalamazoo River
- Muskegon Lake
- White Lake

Sources: 2006 Lake Michigan Lakewide Management Plan; U.S. EPA Great Lakes National Program Office; Great Lakes Information Network.

Management Issue: Beach Closures

Some Lake Michigan beaches experience episodic beach closures because of elevated levels of *E. coli* bacteria. This may be due to stormwater runoff, sewer overflows or even waterfowl droppings. Recent studies show other factors like geography, water depth, weather, beach grooming practices and nearby animal populations contribute to beach closures. (2006 Lake Michigan Lakewide Management Plan)

Need for Improved Beach Monitoring

Issue # 1. A significant delay in determining water quality for the protection of human health: Local beach managers reviewed beach monitoring data and saw that water quality changes occurred in less than 18 hours. Current methods for water testing have at least an 18-hour delay. Local beach managers realized that they could not rely on test results alone to determine the water quality in a timely manner for the protection of human health.

How issue is being addressed: Two approaches are being used to minimize the delay in determining water quality for the protection of human health. One approach is to develop new technology or adapt existing technology to provide results for water quality determinations. This approach requires several areas of expertise and a significant and continued level of funding. U.S. EPA is taking the lead on this effort. Dr. Julie Kinzleman from the City of Racine Health Department in Wisconsin is testing a rapid method as part of a pilot study for U.S. EPA.

The second approach is to develop models that correlate real-time data (observable and measurable) with the delayed bacterial results. This approach requires several areas of expertise and a relatively affordable level of funding for local beach programs. Some of the first predictive or forecasting models were initiated for beaches on Lake Michigan. Models to determine water quality are used for beaches on Lake Michigan in Illinois and Indiana. Additional models are being developed in Michigan. The U.S. EPA, USGS, and the state of Illinois developed and produced a DVD titled, “Beach Models: Predicting Water Quality.” Copies are available upon request.

Changes over time: U.S. EPA and other agencies are developing rapid methods to determine water quality conditions. This effort is expected to continue with an expectation to implement new methods within five years.

Issue #2. An absence of data or lack of information sharing for remediation options or best management practices that improve water quality and support a sustainable, healthy coastal ecosystem: Local beach managers developed methods to improve water quality for the protection of human health. Over time, the best management options to improve water quality for the protection of human health were also supportive of a healthy coastal ecosystem that was sustainable over time.

How issue is being addressed: Local beach managers discovered common problems and worked with each other and several state, federal, and academic researchers and managers to develop a toolbox that included best management practices that would improve water quality and support a sustainable, healthy coastal ecosystem. This is an ongoing effort. Funding opportunities are being investigated to assist in developing an integrated matrix of information and tools that would be available online.

Changes over time: Several beach managers have partnered with different agencies to develop predictive models that provide more accurate water quality conditions that allow better protection for human health. This effort is expected to expand the number of users and the overall scope to the possibility of a regional model, or perhaps all of the coastal water quality of Lake Michigan.

Monitoring Priorities for Lake Michigan Beaches

Local beach managers identified the top ten highest monitoring priorities for Lake Michigan beaches. Due to the length of this material, it has been included as Appendix 2.

There have been 27 actions initiated or completed by local, state, and federal agencies and members of the GLBA in response to these priorities. Lessons learned from these actions are easily transferable and have resulted in significant improvements to beach monitoring programs. However, to develop progressive monitoring strategies, limited funding for routine monitoring programs may need to be redirected towards start-up costs associated with improved technology. Management options have to be carefully considered as funding for routine monitoring programs are sacrificed to achieve long-term improvements.

Changes over time

Several beach managers have partnered with different agencies to develop predictive models for more beaches and they continue to improve existing models. Predictive beach models provide real-time information for water quality conditions which allow better protection for human health. It is expected that more water quality models will be developed for individual beaches with the possibility that a regional model could be developed that would integrate all of the Lake Michigan beaches. Improvements with rapid methods for bacteria or pathogen monitoring will further improve the efficiency in determining current conditions and the factors that change water quality conditions.

Local beach managers are implementing best management practices which are proving to be cost-effective and sustainable. There is a need for these best management practices to be compiled to provide easier distribution and raise awareness that local beach managers should consider options that improve water quality and support a sustainable, healthy coastal ecosystem.

Several beaches that previously reported elevated bacteria levels are now reporting better water quality data. Improved water quality has resulted in fewer beach closures due to remediation efforts. Beaches with existing elevated bacteria levels have more options and tools to further investigate potential sources of contamination. This type of work will continue as funding allows.

What needs to be better defined so management options can be determined?

Sources of contamination need to be better defined so management can effectively minimize and or eliminate the contamination. Improvements in beach water quality can be made as sources of contamination are identified and corrected. Routine monitoring practices are able to determine that water quality may be contaminated but are not able to determine sources.

Management options for improved beach monitoring

One of the toughest management options is to determine when routine monitoring is no longer cost-effective and funding needs to be directed towards improvements to the beach monitoring program. For example, one of the management options is to use limited funds for strategic monitoring and source tracking methods at the expense of routine monitoring practices at beaches that have consistently excellent or consistently poor water quality. Beaches that have consistently excellent water quality are likely to have a lower health risk and may not need routine monitoring. Beaches that have consistently poor water quality are not likely to improve without remediation. Limited funding that had been used for routine monitoring may be better spent for strategic monitoring and source tracking efforts until sources of contamination can be identified and remediated. Another example is when routine monitoring is no longer acceptable due to the significant delay in getting the results and funding is directed towards the development of a predictive model. Several beach managers have commented that decisions about beach status can be inaccurate up to 100% of the time when using data from routine monitoring. Predictive models are improving their accuracy with some models achieving 90% and higher accuracy in predicting water quality conditions. Again, limited funding that had been used for routine monitoring may be better spent for the development of a predictive model.

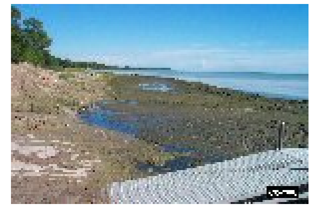
Beach managers are using small scale wetland areas to buffer effects of stormwater runoff to protect beach water. Beach managers are beginning to look at near shore and ground water data in some areas.

Table 1. 2006 Lake Michigan Beach Summary

State	Counties	Monitored beaches	Not Monitored beaches	Actions (beach closure or advisory)	Days of actions taken	Beaches Affected	Total Beaches
IL	2	54	19	657	657	54	73
IN	3	25	0	103	179	13	25
MI	18	110	189	25	39	22	299
WI	11	77	68	609	196	60	145
Totals	**34**	**266**	**276**	**1394**	**1071**	**149**	**542**

Cladophora in the Near Shore Zone and Beach Health

Issue: There has been a recent resurgence of macroalgae, predominantly *Cladophora*, along the coast of Lake Michigan and other Great Lakes. It grows on submerged rocks, logs, and on mussel shells or other hard surfaces. Because of Lake Michigan's water clarity it has been observed growing at well over 30 feet of water depth. Wind and wave action cause the algae to break free from the lake bottom and wash up on shore. These algae blooms lead to unsightly and foul-smelling beaches and have negative economic consequences as a result of the lowered beach use. In addition, *Cladophora* blooms result in reduced quality of drinking water and decreased property values.



Reasons for the current resurgence are unknown. Possible causes include increased nutrient inputs, increased water clarity, increased water temperature and changing lake level. While there have been some efforts to remove *Cladophora* from beaches, ultimately the solution to the *Cladophora* problem requires the identification of the factors promoting growth in the lake, and if possible the mitigation of those factors.

It is unknown if there are increased nutrient concentrations entering the lake via streams and rivers or if zebra mussels redistribute existing nutrients from the phytoplankton they consume to the *Cladophora*. Both may be happening. Work on the Milwaukee River indicates that input of the nutrient most likely to foster *Cladophora* growth, phosphorus, has increased in recent years.

Nuisance levels of Cladophora were also a problem in the 1960s and 1970s. Research linked these blooms to high phosphorus levels in the water, mainly as a result of human activities such as fertilizing lawns, poorly maintained septic systems, inadequate sewage treatment, agricultural runoff and detergents containing phosphorus. Due to tighter restrictions, open water phosphorus levels declined during the 1970s and Cladophora blooms were largely absent in the 1980s and 90s. Phosphorus levels in Lake Michigan continue to remain below the thresholds set in the 1970s, but recent research suggests that the invasion of zebra and quagga mussels in the Great Lakes are responsible for the increase in algae by increasing the availability of phosphorus for Cladophora and increasing water clarity. Because zebra mussel populations cannot be controlled, the only management option is to reduce phosphorus entering Lake Michigan.

Beach season data exhibits a continued number of beach closings. The presence of cladophora in the near shore zone directly impacts beach health. Through a current review of the Great Lakes Water Quality Agreement, there is a renewed desire to model the near shore areas of Lake Michigan and other Great Lakes to better address the return of cladophora and near shore processes related to beach health. Researchers are revising their models to account for the influence of mussels and near shore processes related to beach closure. Near shore data is likely needed to accomplish modeling of cladophora and beach health issues. Thus, a principal gap to fill is a comprehensive near shore/coastal program that integrates with watershed/tributaries and offshore monitoring programs.

Sources: 2006 Lake Michigan LaMP; UW-Milwaukee Great Lakes Water Institute; Wisconsin Department of Natural Resources

Management Issue: Drinking Water-Borne Illnesses

Issue: Although drinking water in the Lake Michigan basin is generally of good quality, there have been sporadic outbreaks of illness related to drinking water pathogens. Drinking water is usually sampled after treatment.

The basic challenges and monitoring needs regarding drinking water are:

- To understand possible vulnerabilities in water sources and prepare protection plans
- To monitor for possible new contaminants

- To understand the implications of and monitor groundwater depletion in the basin as it relates to Lake Michigan
- To educate the public on the hydrological cycle and the need for stewardship of both drinking water quantity and quality
- Need for Operations and Maintenance Plans for infrastructure
- Research needed on health efforts of contaminants and safe levels established

Management options include:
- Seek funding to develop a source water protection GIS system.
- Enhance local public water supply security
- Identify resources for public water suppliers to ensure that by 2011, 80% of the community water systems will be substantially implementing source water protection plans

Management Issue: Pathways of Contamination

Issue: Sediments, air, land, and water continue to be sources or pathways of contamination that affect the integrity of the Lake Michigan ecosystem. While regulatory and remediation programs reduce pollutant sources, ongoing releases and the region's legacy of contamination continue to serve as sources of pollutants.

The basic challenges and needs that come with this issue include:
- Need for sustainable regional growth (traditional growth patterns have led to demands for new power generating plants and emissions)
- Research on phosphorus sources and near shore effects
- Research on conversion of mercury to methyl mercury
- Additional monitoring and data needed on emerging contaminants
- Clean-up and delisting of 10 Areas of Concern (see details – first management issue listed)

Some of the key management options to address this issue include:
- Develop a better understanding of the natural dynamics that affect pollutant distribution in the Lake Michigan ecosystem and why near shore and open lake can have wide variances
- Reduce pollutant loads with effective control and pollution control measures
- Build on the Lake Michigan Tributary Monitoring Project of 2005 and develop a 10-year trend analysis based on the 1994-95 Mass Balance project
- Work to address and delist contaminated sediment sites
- Investigate nutrient contributions from the agricultural sector and nonpoint sources during wet weather. Determine if nutrient levels are linked to *Cladophora* blooms (See *Cladophora in the Near Shore Zone and Beach Health* above.)
- Consider transport of pesticides on vegetation transported downstream and fate of pesticide residue during ecological risk assessments for registration and review.

The findings of the Lake Michigan Mass Balance Study (LMMBS) – a multimillion dollar, multiagency effort to measure the loadings, fate, and transport of contaminants within Lake Michigan – will allow decision-makers to better understand pollution pathways and adopt policies to address pollutant sources. The LMMBS involved a substantial amount of data collection between 1993 and 1995 on Lake Michigan water, its tributaries, air, sediment, and biota. Research was conducted to evaluate processes such as air-water exchange and the sediment-water interface. The project focused on PCBs, trans-nonachlor, atrazine, and total mercury; tributary and air deposition samples also were analyzed for additional parameters such as trace metals, other chlorinated pesticides, and nutrients. The development of a mass balance model, the final component of the study, was completed in 2005. The LMMB model results can be found at www.epa.gov/glnpo/lmmb/results.html.

Management Issue: Loss and Alteration of Great Lakes Coastal Wetlands

Issue: Since European settlement began over 150 years ago, Lake Michigan has lost approximately 50% of its coastal wetlands.

Illinois riverine coastal wetland

Unlike other monitoring components such as contaminants or presence of elevated *E. coli* levels on beaches, specific protocols for monitoring the thousands of wetland types occurring in U.S. coastal regions have not been developed. Due to the differences in wetland function, species composition, water chemistry parameters, geomorphology, and other characteristics, it is extremely difficult to compare the quality of wetlands both within and between ecoregions. Thus, it will be necessary for each state choosing to participate in the National Monitoring Network to tailor protocols to meet the attributes and needs of its wetlands and its wetland regulatory programs. Each entity can, however, use similar methods to identify its particular needs.

Great Lakes coastal wetlands are some of the most biologically diverse ecosystems in the Midwest, and they are crucial to the health of the Great Lakes basin as a whole. Coastal wetlands serve as spawning and nesting habitat for a variety of animals, help maintain water quality throughout the basin, aid in preventing erosion along exposed shorelines, and offer recreational and tourism opportunities throughout the region. As the population of the region grows and brings with it the threat of additional land conversion for agriculture and industry, adequate protection of coastal wetland resources becomes more important than ever.

The Great Lakes Regional Collaboration’s (GLRC) December 2005 strategy to Restore and Protect the Great Lakes identified preservation and restoration of wetland ecosystems as a major goal in its framework for addressing impacts to Great Lakes ecosystem health. Unfortunately, current wetland management practices continue to result in loss of wetland area and function. Dredging and filling for residential and commercial development continues to take a toll on wetlands, particularly those wetlands on valuable coastal land. Recent studies conducted by the Michigan Land Resource Project developed population trend projections for the years 2020 and 2040. These studies indicated that sprawl will transform the landscape throughout much of the southern Lower Peninsula and many areas of the northwest Lower Peninsula. Trends such as these will tend to break up large tracts of Lower Peninsula forest and other habitats into smaller fragmented and isolated patches (Public Sector Consultants, 2001). In addition to residential sprawl, there has been enormous growth in the numbers of seasonal and vacation homes along the Lake Michigan coastline, which leads to more wetland damage. Another threat to coastal wetlands comes from some shoreline property owners who wish to maintain their coastal parcel as a sandy beach, and will actively groom substrates and remove vegetation. Shoreline grooming and vegetation removal are known to adversely affect macroinvertebrate and fish populations, water chemistry and plant root biomass (Albert 2005, Uzarski et al. 2005).

The goals of the GLRC and better regulatory decision making can be achieved, in part, with each state's commitment to a three-tiered monitoring strategy as outlined in the U.S. Environmental Protection Agency's (U.S.EPA) 2006 publication, *Elements of a State Water Monitoring and Assessment Program for Wetlands* and recommended by the NMN. States must commit to assessing landscape attributes, evaluating the general condition of many wetlands using a Rapid Assessment Method (RAM), and further defining condition using more quantitative methods such as Indices of Biological Integrity. Proper monitoring and subsequent management of wetland resources will lead to better protection of fisheries and wildlife resources, water quality, flood storage, nutrient reduction and delisting of Lake Michigan's 10 Areas of Concern.

Based on this three tiered design, participants in the Lake Michigan Pilot study identified a number of wetland monitoring needs within the basin, as outlined below.

Tier 1- Landscape Level Monitoring:
Using the U.S. Fish and Wildlife Service's National Wetland Inventory and/or the Natural Resource Conservation Service's Natural Resource Inventory, and/or other GIS resources, each state needs to monitor the following landscape attributes:

- Change in spatial coverage of interior and coastal wetlands over time
- Changes in predominant type (forested, emergent, shrub, etc) of coastal and interior wetlands
- Changes in land use throughout coastal watersheds over time
- Assessments of the functional values of wetlands within coastal watersheds (i.e. flood water control, groundwater recharge, fish habitat, etc.)

Tier 2- Rapid Assessments
Each state will need to develop a RAM that is suitable to the particular wetland types occurring in the state and the regulatory program implemented within the state. At a minimum, states in the Lake Michigan basin must develop and implement RAMs that assess the following:

- Hydrological functions of the wetland (i.e. flood control, stormwater treatment, etc)
- Quality of wildlife and fish habitat (i.e. vegetation communities, degree of saturation/inundation, connectivity, habitat alteration, etc)
- Value in pollution and erosion control
- Scenic and recreational value
- Degree of modification to the hydrology and habitat within the wetland
- Intensity of invasive species infestations

Tier 3- Intensive Assessments
The Great Lakes Coastal Wetland Consortium recently developed protocols for intensive biological surveys that may be used throughout the Great Lakes basin. In order to ensure sufficient data is collected, each state bordering Lake Michigan should commit to using GLCWC protocols to monitor the following:

- Chemical and physical attributes
- Plants
- Macroinvertebrates
- Fish
- Birds
- Amphibians

Adoption of a monitoring strategy that incorporates as many of these elements as possible is integral in the developing sound wetland management strategies.

Embayments as Unique Monitoring Areas

Embayments are unique areas within the Great Lakes because, while they are connected to the open water portions of the lakes, they are also partially sheltered from the wind and wave action of the larger lake system. This protection allows unique physical attributes such as warmer water, accumulation of sediments and organic matter, and higher concentrations of nutrients to develop, which in turn leads to the development of unique biological structures. Embayments are often more biologically diverse than other open near shore areas of the lakes. Unfortunately, wind and wave action allow for mixing of the water column and substrates, and without these actions contamination can accumulate rapidly. Many of these areas have been impacted by human activities on land, and some have been identified as AOCs. Their uniqueness and vulnerability makes them ideal for assessing the impacts that can be transferred to the Great Lakes from coastal watersheds. Recent research has suggested that the biological, chemical and physical qualities of embayments are strongly associated with the quality of the adjacent watershed. Thus, we can use information gleaned from embayment monitoring to predict the types of problems and improvements that may be transferred to the larger lake from these coastal watersheds.

The NMN identified 87 embayments within the Great Lakes region, 15 of which are in the Lake Michigan basin. Ideally, a random selection of embayments should be monitored each year to aid in assessment of human disturbances in the basin. Monitoring needs include the following:

- Assessment of the various contaminants present in embayments in comparison to other near shore ecosystems and upstream areas within the watershed.
- Detailed biological assessments of embayments including bacterial contamination, chlorophyll a, Cladophora growth, macroinvertebrates, fish.
- Analysis of suspended and bottom sediments
- Changes in physical attributes of the embayment (i.e. temperature increases, erosion rates, bottom depth, etc)

Currently, embayments are not managed independently of other Great Lakes shorelines unless they have been identified as an AOC. Management issues are often similar to other portions of the lakes including the need for additional research, the need to reduce pollution and sediment loads, and the need to develop sustainable human development practices to ensure embayments are protected and restored as necessary.

III. Inventory

Table 2. Inventory Summary Table
Monitoring Organizations and Resource Components Monitored

++ indicates major monitoring effort*
+ indicates minor monitoring effort*
blank indicates no monitoring effort underway

Organization	Estuaries/ Embayments	Shallow Near Shore	Off Shore (includes deeper near shore)	Rivers	Ground Water	Atmospheric Deposition	Wet lands	Beaches
U.S. EPA		+	+					
NOAA	+ Mussel Watch	+ Mussel Watch; Buoys	+ Buoys					
USGS			+	++	+	+		+
U.S. FWS							++	
NRCS							+	
U.S. EPA - IADN						++		
Illinois EPA	+ Calumet Harbor	+		+	+	IL has a mercury sampler in Northbrook (Chicago suburb)	+	+
Indiana DEM	+ Indiana Harbor Canal at mouth	+		+	+	IN has a mercury network with 1 site at IN Dunes		
Michigan DEQ			+ Water Chemistry Monitoring Program	++	+	MI has a mercury network with a site in Pellston (and maybe one in Musk/GR)	+	+
Michigan DNR							+	
Wisconsin DNR		+		++	+	WI has a mercury network with a site in Milwaukee and a PCB air	+	+

						sampler in Milwaukee		
Organization	**Estuaries/ Embayments**	**Shallow Near Shore**	**Off Shore (includes deeper near shore)**	**Rivers**	**Ground Water**	**Atmospheric Deposition**	**Wet lands**	**Beaches**
Grand Valley State Univ.				+				
UW-Green Bay		+		+				
UW-Milwaukee	+	+		+				+
Grand Traverse Band of Ottawa & Chippewa Indians		+						
Oneida Tribe		+		+				
Green Bay Metropolitan Sewerage District		+		+				
Milwaukee Metropolitan Sewerage District	+	+		+				
Bird Studies Canada							++	
National Wildlife Federation							+	
Tip of the Mitt Watershed Council				+				
Marinette Co., WI Land and Water Conservation Dept.							+	

* 1. Decisions about whether monitoring efforts are major or minor were based on three factors: cost, duration, and geographic extent. If an organization is making a major effort for at least two of these factors, it was judged to be a major effort overall. If an organization has a major effort underway for only one of the factors and a minor effort for the other two, it was judged to be a minor effort overall. Similarly, if an organization has a minor effort underway for all three factors, it was judged to be a minor effort overall. The following guidelines are used to determine whether monitoring efforts were major or minor for each component:

- **Cost**: Major is over $1.0 million. Minor is less than $1.0 million. These funds would be cumulative over five years. The five-year figure was chosen because of the 5-year rotation for probabilistic monitoring of estuaries and near shore coastal environmental components.
- **Duration**: Major is three or more years of ongoing monitoring. Minor is less than three years in duration. The table is intended to show current efforts; thus, organizations that conducted monitoring at some point in the past but which are no longer active were judged to be not applicable and left blank for that component in the table.
- **Geographic Extent**: Major indicates that an organization uses standard procedures and protocols over large areas such as (i) 50% or more of a Network estuary; or (ii) measurement of rivers at the drainage point of HUC-6 or other important river; or (iii) major aquifers in the study area. Minor indicates specific studies in smaller portions of the study area. For example, research studies focused on a few sites would be minor in geographic extent.

* 2. An organization was judged to be not applicable and component columns left blank if there are no current monitoring efforts for that environmental component.

Lake Michigan General Inventory Notes:

- U.S. EPA GLNPO's monitoring program budget was $4.5 million in 1992 compared to $4.7 million in 2007 (personal communication Paul Horvatin, 6/26/2007).

- NOAA monitors waves & weather with buoys in the near shore and has one mid-lake buoy. NOAA also runs the Mussel Watch contaminant monitoring program in zebra mussels.

- USGS runs gauging stations on tributaries. There are no major ongoing contaminant monitoring programs for the Great Lakes.

- IDEM, IEPA, MDEQ and WDNR water quality monitoring programs identify the status of the state's waters up to land's edge. Fish are used to integrate lake contaminant information. Michigan also does contaminant monitoring of bald eagle tissue and herring gull eggs.

Rivers Component Inventory Notes

a. There are three major river monitoring entities (USGS, MI DEQ, WI DNR) and eleven other entities that conduct significant river monitoring in the Lake Michigan basin.
b. We relied on the Lake Michigan monitoring inventory conducted by the GLC and personal knowledge.

Methodology Used to Conduct Inventory

In 2006, the Commission developed a centralized repository of Great Lakes monitoring information, the *Great Lakes Monitoring Inventory and Gap Analysis*. It is the first comprehensive binational inventory of monitoring programs in the Great Lakes basin. Using the inventory and input from U.S. and Canadian monitoring experts, Commission staff assessed the capacity of current programs to respond to established monitoring needs. In addition to highlighting recommendations for improving the overall Great Lakes monitoring regime, the inventory identified gaps, overlaps and opportunities for improved regional coordination. In 1999, the Commission completed a Lake Michigan Monitoring Inventory and associated assessment which was a reference for the 2006 Great Lakes Monitoring Inventory.

For the Lake Michigan pilot study, Commission staff queried the Great Lakes Monitoring Inventory for each of the resource components of the National Monitoring Network and produced a spreadsheet of this information for each component group. Staff re-examined and compared the results of the Inventory query, which included many categories of data and information, to the data and information collection parameters and scale of that proposed in the Network design. Staff then prepared an Excel spreadsheet called "Network Needs" which included the following for each of the Network component groups: (1) Purpose; (2) Defined Parameters; (3) Sampling Frequency; and (4) Monitoring Programs Addressing Need. The Inventory queries and the Network Needs spreadsheet were shared with each resource component workgroup via email and posted on the Lake Michigan Pilot Study wiki web page. These tools served as a basis for further analysis by each component workgroup and a tool to utilize in conducting the gap analyses.

In addition, specific analytes, methods, and data were located by U.S. EPA Region 5 and GLNPO staff to support the national Contaminants Network Refinement Workgroup for the NMN pilot effort. State-prepared Clean Water Act sections 303(d) and 305(b) reports, fish consumption advisories, and water quality monitoring plans were reviewed. Summaries of this information have been provided in appendices to the 2002, 2004, and 2006 Lake Michigan LaMP updates. In short, we could not have prepared this pilot report without these program work products.

IV. Data Management Issues

Data Issues Known Prior to Pilot Study and Those Identified During Inventory

Access to accurate and timely data by members of the scientific, management, and policy community is critical to decision making that affects Great Lakes water resources. To support this need, significant time and money has been spent collecting monitoring data including physical, chemical, biological, and cultural data for the domain. These data have been, and are being collected by a variety of agencies, organizations, and institutions over space and time, and represent a significant asset in better understanding and managing the Great Lakes.

Unfortunately, much of these geographic data remain inconsistent and/or incompatible across organizations and boundaries, and subsequently are not readily available for downstream analysis. This general unavailability of data in the region can be attributed to many things including institutional barriers, security concerns, differing languages (computer and otherwise), and financial constraints, among others.

One such limiting factor are those legacy systems, or “stovepipes,” used to collect, store, and transfer data throughout the region. Owing to antiquated software, hardware, and/or engineering methodologies, stovepipes present a significant obstacle to sharing data by making it too expensive (in terms of time and money) to access the data.

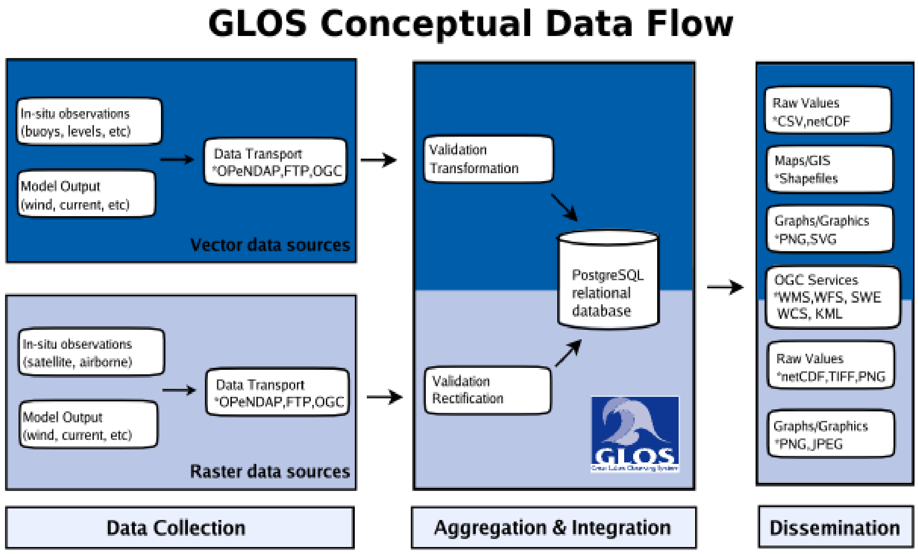
Another issue affecting the usability of monitoring data throughout the region relates to the general “discoverability” of the data. Despite the trove of data being collected, much of it remains hidden behind firewalls or scattered across different web pages. For decision makers and resource managers who depend on timely access to information, it is critically important to making data more readily available.

Possible Solutions to the Identified Issues

To remedy the date accessibility problems affecting the Great Lakes region, several significant inroads are underway. These efforts include standardizing the mechanisms for data encoding and transport, coordinating data collection and integration efforts, and the development of “one stop” clearinghouses to disseminate data.

With the advent of Extensible Markup Language (XML) as a mechanism for storing data, significant strides have been made in developing national and international standards for data exchange. XML has facilitated these efforts by providing a means to encode structured data through user-defined tags, readable by both human and machine alike. Organizations such as the Open Geospatial Consortium (OGC) are using the XML language to develop standards that define ways to better encode and transport data (i.e. through Web Services). Today, XML-based standards such as the Geographic Markup Language (GML) and OGC's Web Feature Service (WFS) and Web Mapping Service (WMS) offer the promise interoperable data exchange across the region.

Other efforts toward making monitoring data more available are those concerned with the integration and normalization of data across the region. The Great Lakes Observing System (GLOS) is a forerunner in this regard, providing real-time access to Great Lakes observing and monitoring data. GLOS provides access to data on climate, meteorology, chemistry, geology, biology and human activities that affect the Great Lakes, their interconnecting waterways and the St. Lawrence River. GLOS draws data about the Great Lakes system from numerous sources, consolidates it, and makes it available via the Internet. This resource helps to meet the needs of resource managers, researchers, educators, commercial shippers, recreational boaters, beach users and homeland security personnel.



The Middleton Data Center (MDC) is another example of a multi-jurisdictional data aggregation and integration effort. MDC, co-located with the USGS Wisconsin Water Science Center, is involved in several projects to develop better coordinated data management systems. One of these projects is a cooperative effort with Milwaukee Metropolitan Sewerage District (MMSD) to aggregate disparate data from universities and local, state, and federal agencies affecting areas within the MMSD's purview. The MDC is also involved with the development of water quality and quantity databases, leveraging XML-based mechanisms (i.e. Web Services) for sharing data across the region. These MDC projects provide positive potential and a baseline for further collaborative data management activities throughout the Lake Michigan watershed.

Another important development in the arena of sharing monitoring data through the region is the advent of metadata-driven, web-based data clearinghouse nodes. These clearinghouses make disparate data infinitely more discoverable through keyword, thematic, and spatially-based queries that allow users to readily find and acquire data.

At the national level, several such portals have sprung up over the past several years. In the U.S. these include Geospatial One Stop (GOS: http://geodata.gov), USGS' National Map (http://nationalmap.gov/), and NASA's Global Change Master Directory (GCMD: http://gcmd.nasa.gov). On the Canadian side, there are the GeoConnections (GeoConnections: http://www.geoconnections.org) and GeoGratis (GeoGratis: http://geogratis.cgdi.gc.ca) clearinghouses. Regionally, the Great Lakes Information Network (GLIN) is providing similar functionality through its GLIN GIS (http://gis.glin.net). The GLIN GIS provides user and organizations the ability to publish their Great Lakes-specific datasets, and makes these data available in a variety of formats and Web Services.

These efforts show that the region is moving towards a much higher level of data sharing and distribution. Owing to the nascent state of these efforts, stable funding streams have not yet been realized, jeopardizing the significant inroads that have been made in recent years. Given the necessity of high-quality, readily-available data about the Great Lakes region, institutionalizing efforts to streamline data access should be a major priority.

Data Access, Management and Delivery

Table 3. Number of Programs and Percentage of all programs with specific attributes relative to data access, management, and delivery. Items in boldface type are the most desired characteristics of a Network data system.

Access Method	Definition	Number of Programs	% of all programs
Not available	Access is limited to the originator and close collaborators.	IN-3	IN-50
Hard copy	The data are available in a format not readily usable by a computer.	N/A	N/A
Digital	Data are available in a tab-delimited or regularly-formatted structure, and may be selected for such elements as location and time.	IL-2 IN-3 MI-4 EPA-1	IL-100 IN-50 MI-44 EPA-100 USGS-100
Web services	**Available for automatic machine-to-machine transfers.**	MI-5 EPA-1	MI-56 EPA-100
Search/Retrieval	**Definition**		
Hidden	Data can not be found by conventional searches.	IN-6 EPA-1	IN-100 EPA-100
Portal	The user may discover the existence of a database, but must gain access to the individual database to make further queries.	IL-2 EPA-1	IL-100 EPA-100
Location - Data Summary	The user may discover sampling sites; only data summaries (e.g., such as "nutrients" or "pesticides," often with period-of-record information) are available. Data available in the form of a geospatial coverage fits this category.	MI-4 EPA-1	MI-44 EPA-100
Location - Value	**The user may discover sampling sites; result values are available.**	MI-5 EPA-1	MI-56 EPA-100 USGS-100
Metadata level	**Definition**		
Undocumented	Metadata information is not available.	N/A	N/A
Database	Metadata information is available that pertains to the database as a whole, but individual entries have minimal documentation.	IL-2	IL-100
ACWI - Partial	Any individual result can be partially documented to ACWI recommendations.	IN-3 MI-9	IN-50 MI-100 USGS-100
ACWI - Full	**Any individual result can be fully documented to ACWI recommendations.**	IN-3 EPA-1	EPA-100
Archive method	**Definition**		
At risk	No formal procedures exist for ensuring the data are preserved for future use.	IN-6	IN-100
Preserved	Data are stored in a secure archive at a single geographic location, therefore prone to catastrophic failure. Retrieval of archived information in the event of catastrophic failure may be problematic.	IL-2	IL-100
Redundancy	**Data are preserved in a failure-resistant system, stored in multiple geographic locations, where they can be dependably retrieved at any time.**	EPA-1	MI-100 EPA-100 USGS-100

Additional Data Management Summary Tables

Entries include data system name and a URL for data access or a general reference of a data center to contact to gain access to the data.

Monitoring Organizations	Table 4.1. Data Management - Lake Michigan Embayments
USGS	NWIS: http://waterdata.usgs.gov/wi/nwis/nwis
U.S. EPA	GLENDA (sediment data): www.epa.gov/glnpo/monitoring/data_proj/glenda/index.html
NOAA	Mussel Watch: www8.nos.noaa.gov/cit/nsandt/download/mw_monitoring.aspx

Monitoring Organizations	Table 4.2. Data Management - Lake Michigan Shallow and Middle Near Shore
USGS	NWIS: http://waterdata.usgs.gov/wi/nwis/nwis
U.S. EPA	GLENDA – no current monitoring (Triax tow unit, TBD sampling plan for both shallow and middle near shore)
NOAA	Mussel Watch - www8.nos.noaa.gov/cit/nsandt/download/mw_monitoring.aspx and wind, wave, water level buoys

Monitoring Organizations	Table 4.3. Data Management - Lake Michigan Off Shore
U.S. EPA	GLENDA: www.epa.gov/glnpo/monitoring/data_proj/glenda/index.html Fish monitoring: www.epa.gov/greatlakes/monitoring/fish/reports/open_lakes.html
NOAA	Mussel Watch: www8.nos.noaa.gov/cit/nsandt/download/mw_monitoring.aspx and wind, wave, water level buoys

Monitoring Organizations	Table 4.4. Data Management - Lake Michigan Rivers
USGS	NWIS: waterdata.usgs.gov/wi/nwis/nwis
Indiana DEM	STORET, AIMS: indiana.gov/miswims
Michigan DEQ	STORET: michigan.gov/miswims
Wisconsin DNR	STORET, SLOH lab portal: wisconisn.gov/miswims

Monitoring Organizations	Table 4.5. Data Management - Lake Michigan Groundwater
U.S. EPA	EPA, multiple years: epa.gov/storet
USGS	USGS, multiple years: waterdata.usgs.gov/nwis/gw
Illinois EPA	epa.state.il.us/water
Indiana DEM	in.gov/dnr/water
Michigan DEQ	michigan.gov/deq
Wisconsin DNR	dnr.state.wi.us/org/water

Monitoring Organizations	Table 4.6. Data Management - Lake Michigan Atmospheric Deposition
U.S. EPA; Environment Canada	Integrated Air Deposition Network (IADN): www.msc.ec.gc.ca/iadn/data/form/form_e.html
Cooperative effort nationwide	National Air Depositioin Network (NADP): nadp.sws.uiuc.edu/

Monitoring Organizations	Table 4.7. Data Management - Lake Michigan Wetlands
Great Lakes Coastal Wetlands Consortium	Via the Great Lakes Commission – www.glc.org/wetlands - wetlands database site not yet active as of December, 2007
Bird Studies Canada	Marsh Monitoring Program - www.bsc-eoc.org/volunteer/glmmp/index.jsp

Monitoring Organizations	Table 4.8. Data Management - Lake Michigan Beaches
U.S. EPA	BEACON: monitoring, notification, and location data for beaches in 35 coastal states, including the Great Lakes Beaches http://oaspub.epa.gov/beacon/beacon_national_page.main • Partner in producing Beach Models: Predicting Water Quality DVD, 38-minute video for predictive models used at beaches in Ohio, Indiana, and Illinois • Partner with Great Lakes Beach Health Research Needs Effort
NOAA	• Partner with Great Lakes Beach Health Research Needs Effort • Grand River-Lake Michigan Monitoring Project
USGS	• Partner with Great Lakes Beach Health Research Needs Effort • Partner in producing Beach Models: Predicting Water Quality DVD, 38-minute video for predictive models used at beaches in Ohio, Indiana, and Illinois • USGS-Indiana: Project S.A.F.E.: www.glsc.usgs.gov/projectSAFE.php • USGS-Wisconsin Great Lakes Beaches: www.wibeaches.us/traverse/f?p=BEACH:HOME:806232506292566 (Sleeping Bear Dunes fish and bird mortality included in this report) • National Wildlife Health Center (NWHC) produces quarterly reports containing information about wildlife mortality events throughout the U.S. and on occasion across North America: http://www.nwhc.usgs.gov/publications/quarterly_reports/index.jsp
Indiana DEM	• USGS-Indiana: Project S.A.F.E.: www.glsc.usgs.gov/projectSAFE.php
Illinois EPA	Illinois (Lake County Department of Health) • www.co.lake.il.us/health/ehs/swimcastdata.asp • www.co.lake.il.us/health/ehs/SwimCastDataAP.asp
Michigan DEQ	• MDEQ Beaches: www.deq.state.mi.us/beach/public/default.aspx • MiSWIMS: www.mcgi.state.mi.us/miswims/
Wisconsin DNR	WNDR Beaches • www.dnr.state.wi.us/org/water/wm/wqs/beaches/ • www.wibeaches.us/traverse/f?p=BEACH:HOME:4042429790421848
University of WI-OshKosh	Greg Kleinheinz, Colleen M. McDermott Beach Sanitary Survey data, algae monitoring, and source tracking data
Michigan State University	Joan Rose: Source tracking data
University of MN	Mike Sadowsky: Beach sanitary survey data, algae monitoring, and source tracking data
Central Michigan University	Elizabeth Alm: Avian influenza in sediments, genetic diversity and similarity in *E.coli* in beach sediments
Racine, Wisconsin	Julie Kinzleman, Pilot testing QPCR methods for enterococci for beach water quality monitoring

Rivers Data Notes

There are issues linking USGS NWIS data and STORET data. Not all recent data from states is in STORET. Not all minor, but significant, monitoring entities enter data in NWIS or STORET.

Wetlands Data Notes

Wetland monitoring information is highly fragmented. Currently, agencies and organizations with an interest in wetlands have few complete data sharing resources. A number of databases exist for specific types of biological data, such as fish collection or endangered species locations, but none of the existing systems focus on coastal wetlands. Searching for the correct data can be a difficult task. The U.S. EPA stores biological and chemical data on its STORET system, but it is difficult to determine whether information in the database was collected at coastal wetland sites, and searching for specific types of data can be arduous. In the future, GLNPO hopes to implement a data storage system developed for those who adopt the Great Lakes Coastal Wetland Consortium (GLCWC) protocols, which are described in the gap analysis section of this document. This would allow easy access to specific wetland data.

Table 5. Quality Assurance/ Quality Control

The Quality Assurance/Quality Control (QA/QC) table below was derived from Figure 4-1 of the Network design report, page 72. A green cell indicates that the program meets the category. An orange cell indicates that the program addresses the category but the information is not necessarily with the data on the web site. A blank cell indicates that the program does not address the category. We attempted to complete each line in the column for a monitoring organization without regard to which of the environmental components the agency is monitoring. Best professional judgment was used to determine what should be in any given cell for an agency using the dominant practices of that organization. For example, if a particular agency maintains metadata for contaminants and nutrients but not for biology, we may have chosen to fill the cell with either green or orange.

	Sample Collection	Sample Processing / Analysis	QA/QC				Metadata		Data Reporting		
	Method availability	Method availability	Replicate samples?	Matrix spikes?	Reference sample?	Split samples?	Recommended metadata maintained?	Availability	Data availability	Report availability	Ancillary data available?
USGS Rivers GW	I, P	I, P	Y	Y	Y	Y	Y	I, P	I	I, P	I
USGS GLSC Fish Off Shore	I, P										
USGS GLSC Fish Trawl Near Shore	I, P	I, P									
USGS Fish Commercial Catch	I								I P		
USGS Beaches National Lakeshore	?	?	?	?	?	?	?	?	?	?	?
NOAA Mussel Watch Shallow Near Shore	I	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
IL EPA Rivers and Shore Surveys Near-shore	I, P	I, P	Y	Y	N	N	Y	R			
IN DEM Rivers and Near-shore Drinking Water Intakes	I. P	I, P	Y	Y	Y	N	Y	R	I	I,P	I
MI DEQ Rivers and Traverse Bay	I, P	I, P (metals/ PCBs); R (nutrients)	Y	Y	Y	N	Y	R	I	I, P	I
WI DNR Rivers	I. P	I, P	Y	Y	Y	N	Y	R	I	I,P	I
GLNPO Fish Monitoring Program Offshore	I, P	I, P	Y	Y			Y	I, P, R			
Integrated Air Deposition on Network Rivers	I, P	I, P	Y	Y	Y	Y	Y	P, R	?	I	?

	Sample Collection	Sample Processing / Analysis	QA/QC				Metadata		Data Reporting		
	Method availability	Method availability	Replicate samples?	Matrix spikes?	Reference sample?	Split samples?	Recommended metadata maintained?	Availability	Data availability	Report availability	Ancillary data available?
Green Bay Wastewater Utility Shallow Near Shore	**N/A**	**P**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**P**	**N/A**	**N/A**	**N/A**
Milwaukee Wastewater Utility Shallow Near Shore Nutrients/ Pathogens	**I**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**I, R**	**N/A**	**N/A**	**N/A**

V. Gap Analysis

In this table, we attempt to quantify some of the gaps that arise during the comparison of the Network design with ongoing monitoring efforts in the Lake Michigan basin. Row 1 is based upon the specifications in the Network design document. Rows 2-6 give the percentages of various types of gaps that may exist between ongoing monitoring and Network design. Row 7 acknowledges the fact that local or regional needs may require more monitoring than what is specified in the Network design such as additional tributaries or additional monitoring for a given resource component.

Table 6. Gap Analysis.

	Type of Gap	Embayments (Estuaries)	Shallow Near Shore	Medium Near Shore	Off Shore	Rivers	Ground Water	Atmospheric Deposition	Wetlands	Beaches
Row 1	Number of sites or level of effort needed for national Network design	8 (eventually all 15 embayments in Lake MI would have to be monitored. The 8 monitoring points are only a sample set for 1 year of monitoring.)	20	15 100%	9 (spring 13; summer 21)	17	25	Per technical experts	70	268 beaches (currently monitored)
Row 2	% Sites or level of effort where national monitoring is complete	0%	0%	0%	100%	0%	0	National design based on Great Lakes	0	Estimated 40 beaches have actual data and models
Row 3	% Sites or level of effort where there is no ongoing Monitoring	53%	60%	100%	0%	0%	80%	National design based on Great Lakes	90%	276 beaches (50%)
Row 4	% Sites or level of effort with ongoing monitoring but need to increase frequency for National design	0%	0%	0%	0%	85%	20%	National design based on Great Lakes	10%	110 beaches in Michigan are monitored once per week and should be monitored more frequently as beaches in IN, IL,

										and WI. 276 more beaches in IL, MI, and WI are not monitored at all. Indiana monitors all 25 of their beaches.
	Type of Gap	**Embayments (Estuaries)**	**Shallow Near Shore**	**Medium Near Shore**	**Off Shore**	**Rivers**	**Ground Water**	**Atmospheric Deposition**	**Wetlands**	**Beaches**
Row 5	% Sites or level of effort with on-going monitoring but need to add specific analytes or observations or change detection levels for National design	47%	100%	0%	0%	100%	5%	National design based on Great Lakes	10%	100% of the 268 currently monitored beaches, as well as 100% of the 276 beaches with no monitoring.
Row 6	% Sites or level of effort with other type of gap when compared to National design	100%	100%	100%	0%	0%	0%	National design based on Great Lakes	Unknown	238 (89%) of the currently monitored beaches; 276 (100%) of the beaches with no monitoring
Row 7	Number of additional sites or increased level of effort with ongoing monitoring to address local or regional needs	100%	12	100%	2	3	20%	See recommendations in Gap Analysis Notes below	5%	238 beaches that are currently monitored have local and regional needs yet to be addressed.

Gap Analysis Table Notes:

Embayments

The NMN design recommends sampling using a probability based design (illustrated in Figure 3-6 on page 49 of the Network design report). The NMN protocol defined 87 embayments within the Great Lakes basin. Fifteen of these are along the Lake Michigan shoreline. The report (p. 31) specifies the number of sites within each embayment to be variable within each embayment and once per year sampling. The Network design report (Table 3-2 on page 31) lists organic and inorganic contaminants, biological, sediments, and physical setting measurement for this resource component, for which the recommended monitoring frequency is once per year. Currently, none of the Lake Michigan embayments are being measured for the suite of physical, chemical, and biological constituents recommended in the Network design report. At this point, there is no comprehensive monitoring program focused specifically on embayments in the basin. Seven of 15 Lake Michigan embayments are not currently a part of any monitoring program. State fish chemical and sediment monitoring is incomplete (see Appendix 11). However, various elements are sampled within a number of embayments as part of some other monitoring program, as follows:

- Indiana Harbor: Mussel Watch, IDEM water sampling, AOC sampling
- Calumet Harbor: Mussel Watch, IEPA south shore lake survey, AOC sampling
- Milwaukee Harbor: Mussel Watch, MMSD, WDNR sampling, AOC sampling
- Grand Traverse embayment at Leelanau State Park: Mussel Watch
- Little Traverse Bay: Tip of the Mitt Watershed Council's water quality studies (ongoing monitoring?)
- Little Bay de Noc: MDNR fishery
- Big Bay de Noc: MDNR fishery

Recommendations: Continue planning for the 2010 National Coastal Assessment, the first to include the Great Lakes. Compare existing monitoring summarized in Appendix 11 to national contaminant refinement workgroup draft recommendations (marked with x's).

Shallow Near Shore

1. The number of shallow near shore sites (20) was counted from Figure 3.5 on page 48 of the Network design report - Great Lakes Nearshore/Offshore Sampling design: Panel 1. The number of sites per lake is 50 in a lakewide, depth-stratified design. Shallow nearshore monitoring stations in Lake Michigan follow:

IDEM: Six drinking water intakes sampled at the inland end of the pipe & lake water from Dunes St. Park

IEPA: 21 stations south from Waukegan to north of Burns Harbor, Indiana (see Appendix 3).

Mussel Watch: three of the seven sampling stations could be included for an embayment station. The other four stations provide additional shallow near shore coverage.

Additional municipal water intakes with raw water analysis were not identified.

2. The number of existing sampling stations exceeds the total number allotted, and the water chemistry sites are only in the southern portion of Lake Michigan. Given the invasive species, cladophora, pathogen, and nutrient nearshore issues north of this area, the Lake Michigan Pilot presumes that only 25% of the design is satisfied by existing stations.

3. Current level of effort is 40% estimated relative to the need for chemical, physical, and biological monitoring and NMN design.

4. Monitoring frequency is specified as once to twice per year. Mussel Watch is an annual program with a few gaps. The IDEM and IEPA water sampling is at least once per year.

5. The number of additional sites, 12, is 60% of 20.

Medium Near Shore
1. The number in Row 1 was derived from Figure 3.5 of the Network design report - Great Lakes sampling design, near shore and off shore sites.
2. There are no known monitoring programs in the medium near shore.

Off Shore
Elsewhere, the NMN design for monitoring is based on a randomized grid. An exception is made for this subcomponent. "Targeted sampling of the Great Lakes will use fixed sites and continue historical monitoring efforts in the offshore waters conducted under the Great Lakes Water Quality Agreement and the International Joint Commission" (p. 46 of the Network design report). Sampling locations for existing monitoring networks on the Great Lakes, dating from the early 1980's are based on alternative criteria. In the offshore area, water mass movement appears to be sufficient to "randomize" the sampling resource being sampled. As part of the original Great Lakes Environmental Monitoring and Assessment Program (EMAP) in the late 1980's and early 1990's, a comparison study of the existing deterministic sample sites and a randomized grid was performed. The results of that comparison were that very little difference existed between the water chemistry values obtained from either design, with the exception that some randomized grid sites were placed at locations not representative of the offshore area.

Currently, U.S. EPA, Great Lakes National Program Office and NOAA Great Lakes Environmental Research Laboratory are the entities with long-term monitoring programs on Lake Michigan. U.S. EPA visits eleven or more offshore sites twice per year collecting water chemistry and biological data as part of its mandate based on the Great Lakes Water Quality Agreement and the Clean Water Act. NOAA visits one site on a more frequent basis throughout each year. These monitoring programs complement each other, giving both wide spatial coverage and frequent temporal coverage.

Recommendation: Maintain the current offshore programs for both agencies, and supplement the temporally more intense NOAA program with at least one more station in the offshore area located near Milwaukee, WI.

Rivers
All 20 of the river sites being proposed for the Lake Michigan portion of the national monitoring network currently have streamflow gaging stations on them. Fifteen sites have some ongoing water quality monitoring. None of the sites has the complete proposed constituent monitoring data set or complete correspondence with the proposed frequency. All stream gaging is being done according to proposed protocols. All water quality monitoring is being done according to protocols approved by either USGS or U.S. EPA for the constituent of interest. Three additional rivers (Grand Calumet, Sheboygan, and Manitowoc) are also proposed for addition to the NMN design. Each of these rivers has ongoing streamflow and water quality monitoring. These 20 proposed network sites will only provide coverage for about 71% of the river inflow to Lake Michigan. While we do not feel this is adequate coverage, in and of itself, we believe that when coordinated with monitoring at other river sites in the basin it is possible to determine if short-term added monitoring is needed to supplement the network.

Additionally, regarding Great Lakes AOCs (see Management Issues section), a complete and thorough set of monitoring protocols to measure the restoration of their beneficial use impairments is lacking. Since most have a contaminated sediment component, the monitoring of the AOCs cannot be met by near shore or tributary river monitoring.

Atmospheric Deposition
Recommendations include:

1. Passive sampling network – per Great Lakes Observing System (GLOS) recommendations.

2. More urban data – per IADN peer reviews, national design, and GLOS.
3. Screening and surveillance of newer chemicals (e.g. siloxanes) per GLOS, IADN, etc.
4. Uniform or coordinated mercury network per the National Air Deposition Program (NADP), the Mercury Trends Network (See Appendix 10), GLOS, and the Great Lakes Air Deposition monitoring program (See www.glc.org/glad/pdf/MercuryReport_May07.pdf - *Mercury Deposition Monitoring in the Great Lakes States: Current Activities and Future Directions - A report of the Great Lakes State Mercury Deposition Monitoring Discussion Group*.)

Wetlands
Prior to the establishment of the GLRC and the release of the U.S.EPA's guidelines for development of a wetland monitoring program in 2006, few coordinated monitoring efforts had been initiated for coastal wetlands. Historically, each agency and organization has had disparate goals and monitoring techniques, and no organization has overarching responsibility for data management. This has lead to significant fragmentation of biological, chemical, physical and landscape information across federal, state, provincial, tribal and local agencies. It is clear from the table above that glaring gaps exist in wetland monitoring. With the establishment of new guidelines (U.S. EPA 2006) and reiteration of the importance of wetland monitoring, several new efforts have begun to allow better monitoring of wetland resources.

The MDEQ and WDNR have both nearly completed Rapid Assessment Methods (RAMs) for their states, and both Indiana and Illinois are considering utilizing the well established Ohio RAM, since their states are in similar ecoregions. These programs correspond to the Level II analysis recommended by the U.S.EPA. RAMs, however, are likely to classify any coastal wetland resource as a very high quality wetland, thus, these protocols are best utilized at inland wetlands. A more thorough analysis may be conducted in coastal wetlands using a Tier III analysis. In addition, the Great Lakes Coastal Wetlands Consortium (GLCWC) plans to release complete wetland assessment protocols corresponding to the Tier III recommended monitoring parameters in late 2007. The protocols will cover assessment of wetland chemistry and landscape features, as well as biological indicators for fish, macroinvertebrates, vegetation, birds, and amphibians. With the establishment of these protocols, it is hoped that coastal wetland monitoring data will be less fragmented across the basin and more easily shared among agencies and organizations.

Currently, the largest Lake Michigan monitoring effort is organized through Bird Studies Canada's Marsh Monitoring Program. This program sends volunteers in to the field to collect data on wetland bird and amphibian species. Data from the monitoring is compiled into reports every five years. A second major monitoring effort includes the ongoing National Wetlands Inventory (NWI) program conducted by the U.S. Fish and Wildlife Service (USFWS). This program maps wetlands using remote sensing and follows the status and trends of wetland loss and gain throughout the nation. Minor monitoring efforts include the Natural Resources Conservation Service's (NRCS) National Resource Inventory, fish collection by the State of Michigan's Department of Natural Resources(MDNR), Fisheries Division, wetland status and trends analysis and wetland inventory mapping by the Wisconsin Department of Natural Resources (WDNR) and a number of smaller volunteer or local efforts.

The number of required wetland monitoring sites in the Gap Analysis Summary Table (Table 6) was derived from GLCWC protocols, which state that a minimum of 14 wetland sites must be monitored for each ecoregion of each Great Lake in order to adequately assess coastal wetland health. Since Lake Michigan has a total of five ecoregions, as defined by the Level III Ecoregion maps developed by the Commission for Environmental Cooperation, a minimum of 70 sites must be monitored to achieve a complete data set for Lake Michigan wetlands. If 70 coastal wetland sites were randomly chosen from throughout the Lake Michigan basin, it is expected that ongoing monitoring would be taking place at only a small fraction of the sites. Thus, we estimated that over 90% of wetland sites would have no ongoing monitoring efforts. Even in locations where wetland monitoring is being conducted, the frequency of site visits would likely need to be increased, since the GLCWC recommends that all 14 sites in each ecoregion be revisited every four years, and that three of the 14 sites should be visited in consecutive years. We estimate that of the remaining 10% of sites where some wetland monitoring is taking place, 0% are visited with this frequency. Sites that do have ongoing monitoring, such as those that are monitored by volunteer groups, almost always lack certain components of a well rounded monitoring program, and would need to add in macroinvertebrate sampling, plant sampling and other components to collect adequate data. We are not aware of any site that is conducting a complete wetland monitoring program in Lake Michigan and, thus, 100% of sites need to monitor additional analytes or parameters. Finally, the component workgroup determined that a minor number, estimated at 5%, of coastal wetlands have ongoing monitoring being conducted as part of a local effort (e.g. purple loosestrife monitoring in Marinette County, WI).

Beaches
Strategic monitoring that involves spatial, temporal, and source tracking methods is needed. Improvements to beach water quality are accomplished with strategic monitoring in conjunction with a thorough knowledge of the beach and its watershed and a routine monitoring program. However, to develop more progressive monitoring strategies, limited funding for routine monitoring programs may need to be redirected towards start-up costs associated with improved technology.

V-A. Contaminant Monitoring in the Lake Michigan Watershed

Federal and state agencies monitor contaminants in Lake Michigan's off shore and shallow near shore waters. No monitoring programs were identified in the medium near shore as defined by the NMN for Lake Michigan. States monitor Lake Michigan watershed water quality in rivers and specific contaminants as bioaccumulated in predator fish in order to prepare fish consumption advice and to prepare Clean Water Act Consolidated Section 303(d)/305(b) reports. On a more local basis, the Green Bay and Milwaukee wastewater utilities monitor nutrients and/or pathogens. Station locations in the Lake Michigan watershed are identified in Appendices 3-9.

Appendix 11 was derived from an Excel worksheet compiling the 294 parameters measured routinely in the past three years, of which about 220 are identified by chemical abstract service numbers. The 294 rows corresponded to nutrients, naturally occurring elements, pollutant metals and organic chemicals, and physical characteristics like temperature, pH, or sample counts. If the parameter was monitored in multiple media, then the media were identified in the cell corresponding to the State or Federal monitoring program column. Six columns corresponded to four states' water quality monitoring programs and four columns represented the GLNPO water and fish monitoring programs, the National Oceanic and Atmospheric Administration's Mussel Watch and the Integrated Air Deposition Network (IADN). Air monitoring programs without a toxic substance emphasis were not included in this worksheet. State contaminant monitoring programs typically end at the tributary mouth or lake's edge; Illinois is an exception as it has a cooperative agreement with the City of Chicago to do shore surveys.

Appendix 11 can be used to judge whether monitoring programs today: (1) measure parameters along a pristine to disturbed condition gradient; (2) provide a continuity of measurements that allow linkages among the resources; and (3) monitor the same constituents in no fewer than three of the river, embayment, shallow near shore, medium near shore, and off shore Great Lakes components. With these judgments, we can evaluate the suitability of existing monitoring programs as a backbone for the National Monitoring Network in the Great Lakes. The following table is an attempt to draw conclusions quickly from the worksheet by showing how many parameters are monitored by all four states and all federal monitoring programs. For example, if a state samples water quality at one fixed river location and no federal program monitors that constituent, then no gradient is measured until the river is included in a rotating basin probabilistic program or once every five years.

Table 7. The number of states monitoring a parameter in the database is the top row of the table. The number of federal programs monitoring the same parameter is the first column of the table. The cell entries sum to 285 while the number of parameters in the database is 294, indicating a tally error of about 3%.

	Number of States Monitoring x Parameter					
Number of federal programs monitoring x parameter		zero	one	two	three	four
	zero		67	18	8	0
	one	64	43	11	8	6
	two	14	19	8	2	5
	three	2	3	3	4	0
	four	0	0	0	0	0

The total number of parameters in the worksheet gives an initial impression of a robust program. That is not correct because nitrogen species account for 11 of the 294 parameters and there are about 55 PCB congeners or congener groups, or roughly 20%. In addition, about 20 parameter groups of polycyclic aromatic hydrocarbon compounds are monitored only by the Mussel Watch program. Illinois monitors Lake Michigan for semi-volatile organics, contributing to the relatively large number of parameters in only one state program and no federal programs. Michigan and Wisconsin monitor for some of the same PCB congeners and congener groups as IADN and Mussel Watch, accounting for higher numbers in the one state and one or two federal programs matrix cells. Additional factors leading to the high one state-zero federal program count include in-use pesticides and the variety of ways to measure nutrients. All of the states monitor temperature, pH, chloride, cadmium, chromium, copper, nickel, sodium, zinc, PCBs in fish and/or water, and mercury in tissue and/or water.

Of these 11 common parameters, GLNPO reports total PCBs in its fish monitoring program, representing the off shore while Mussel Watch and IADN report on a congener-specific basis representing the shallow near shore. IADN reports on both a congener-specific basis and a total PCB basis. Also, depending on the IADN station, the data either represents lakewide averages (Sleeping Bear Dunes) or more localized conditions (Chicago). (Note: Lake trout likely represent lakewide or at least regional conditions, whereas salmon are collected in tributaries which likely represent a combination of off shore and near shore exposures.) There is not a pristine to disturbed condition gradient measured since all compartments are contaminated. The concentration in the open water is so low that monitoring it makes little sense. However, it depends on the focus of the monitoring. Water data is needed to estimate atmospheric loads of PCBs and other PBTs including mercury. Water data is also useful to determine contaminant fate and cycling. Therefore, it may make sense to monitor water concentrations every three to five years instead of monthly or annually.

It would be helpful to better understand where fish are most exposed to PCBs – whether it is in the rivers, shallow near shore, medium near shore, or offshore – and at what age as this could affect stocking decisions and site-specific remediation. The 2006 Lake Michigan LaMP manipulated fish consumption advisory information by species and species' preferred habitat, but findings that more species are subject to mercury advisories inland relative to the near shore and in the near shore relative to the offshore may merely indicate greater species diversity in shallower water.

To summarize preliminary findings from Appendix 11 in the context of Table 3-1 in *A National Water Quality Monitoring Network for U.S. Coastal Waters and their Tributaries,* physical monitoring in the form of trace metals, carbon, pesticides, PCBs, and PAHs in sediment is not routine and therefore is a gap. Chemical inorganic monitoring does not usually include dissolved oxygen, conductance, turbidity, color, and alkalinity measured using the same method. With respect to major ions, calcium, magnesium, potassium, and sulfate are not usually measured in water. With respect to nutrients, a variety of nitrogen forms and phosphorus are measured in an inconsistent way across the Lake Michigan watershed while silica is routinely measured by three States. Among recommended metals and metalloids, there are also gaps.

V-B. Nutrient Monitoring In the Lake Michigan Watershed

A Nutrients Workgroup produced guidance concerning the monitoring of nutrients in U.S. waters. The guidance identified priority nutrients and associated parameters that should be included in a national monitoring network. Federal and state agencies conduct extensive water quality monitoring for most of these parameters in Lake Michigan and its tributaries. The U.S. EPA vessel, the Research Vessel Lake Guardian, samples offshore waters in Lake Michigan each year for multiple parameters, including chloride, nitrate+nitrite, total phosphorus, silica, chlorophyll a, temperature, dissolved oxygen, pH, conductivity, and transparency (Table 8).

The Lake Michigan states conduct water quality monitoring in some near shore areas. Indiana monitors nine sites, Michigan has monitored 13 sites, and Wisconsin monitors 15 sites in Lake Michigan near shore waters and embayments. Indiana and Wisconsin analyze samples for many nutrient parameters, while most MDEQ near shore samples are analyzed only for conventional parameters (see Table 9).

Extensive monitoring of Lake Michigan tributaries is carried out by the U.S. Geological Survey and the states of Indiana, Michigan, and Wisconsin. The USGS has flow gages at 35 sites in the Lake Michigan watershed, and measures temperature and/or dissolved oxygen at 10 locations. Nutrient data are also collected at a small number of these sites. Indiana routinely monitors four tributaries, Michigan monitors 11 tributaries, and Wisconsin monitors nine tributaries. All three states analyze water samples for nutrients and associated parameters, although not all of the recommended parameters (Table 10).

Other federal, state, and local agencies – as well as university scientists – also monitor Lake Michigan and its tributaries. However, their monitoring is generally targeted for specific projects and for a limited period of time.

Recommended detection limits (as developed by the national Nutrient Workgroup) for various nutrient parameters are listed in Table 11, along with actual detection/quantification levels for the U.S. Geological Survey, Indiana, Michigan, and Wisconsin. Actual monitoring agency limits for the nitrogen parameters generally are higher than the recommended detection levels. Actual limits for many other parameters, including total phosphorus, are at or below the recommended detection limits. As mentioned above, the states and federal agencies do not routinely monitor for several of the recommended nutrients and associated parameters.

Table 8. Nutrient Monitoring in Lake Michigan Off Shore Waters.

Parameter	U.S. EPA
Tier 1	
Total nitrogen	
Dissolved ammonium	
Dissolved nitrate+nitrite	X
Total phosphorus	X
Dissolved ortho phosphate	
Dissolved silica	X
Tier 2	
Total dissolved nitrogen	

Total dissolved phosphorus	
Particulate nitrogen	
Particulate phosphorus	
Response Variables	
Chlorophyll a	X
Dissolved oxygen	X
Conductivity	X
Ancillary Analyses	
Dissolved organic carbon	
Dissolved inorganic carbon	
pH	X
Total suspended sediments	
Photosynthetically active radiation	
Particulate carbon	

Table 9. Nutrient Monitoring in Lake Michigan Near Shore Waters. See Appendix 11 for nutrients monitored by Illinois.

Parameters	**Indiana**	**Michigan**	**Wisconsin**
Tier 1			
Total nitrogen	X		X
Dissolved ammonium	X		X
Dissolved nitrate+nitrite	X		X
Total phosphorus	X		X
Dissolved ortho phosphate			X
Dissolved silica	X		
Tier 2			
Total dissolved nitrogen			
Total dissolved phosphorus			X
Particulate nitrogen			
Particulate phosphorus			
Response Variables			
Chlorophyll a		X	X
Dissolved oxygen	X	X	X
Conductivity	X	X	X
Ancillary Analyses			
Dissolved organic carbon			
Dissolved inorganic carbon			
pH	X	X	
Total suspended sediments	X		X
Photosynthetically active radiation			
Particulate carbon			

Table 10. Nutrient Monitoring in Lake Michigan Tributaries.

Parameters	Indiana	Michigan	Wisconsin
Tier 1			
Total nitrogen	X	X	X
Dissolved ammonium	X	X	X
Dissolved nitrate+nitrite	X	X	X
Total phosphorus	X	X	X
Dissolved ortho phosphate		X	X
Dissolved silica	X		
Tier 2			
Total dissolved nitrogen			
Total dissolved phosphorus			X
Particulate nitrogen			
Particulate phosphorus			
Response Variables			
Chlorophyll a			X
Dissolved oxygen	X	X	X
Conductivity	X	X	X
Ancillary Analyses			
Dissolved organic carbon			
Dissolved inorganic carbon			
pH	X	X	X
Total suspended sediments	X	X	X
Photosynthetically active radiation			
Particulate carbon			

Table 11. Analytical detection/quantification limits for nutrient parameters.

Analyte	Recommended Detection limit	USGS (Detection)	IN (Reporting)	MI (Quantification)	WI
Dissolved ammonium	0.007 mg N L^{-1}	0.05 mg/L	0.01 mg/L	0.01 mg/L	0.015 mg/l
Dissolved nitrate plus nitrite	0.007 mg N L^{-1}	0.05 mg/L	0.01 mg/L	0.01 mg/L	0.019 mg/l
Dissolved ortho phosphate	0.001 mg P L^{-1}	0.01 mg/L		0.003 mg/L	0.002 mg/l
Dissolved silicate	0.003 mg Si L^{-1}	0.1 mg/L	6 mg/L		
Particulate nitrogen	0.01%				
Particulate phosphorus	0.005 mg P L^{-1}				
Total dissolved nitrogen	0.001 mg N L^{-1}	0.001 mg/L			
Total nitrogen	0.03 mg N L^{-1}	0.015 mg/L	0.1 mg/L (TKN)	0.1 mg/L (TKN)	0.14 mg/l (TKN)
Total dissolved phosphorus	0.01 mg P L^{-1}	0.01 mg/L			
Total phosphorus	0.01 mg P L^{-1}	0.007 mg/L	0.01 mg/L	0.005 mg/L	0.005 mg/l
Chlorophyll *a*	0.01 μg L^{-1}				
Dissolved oxygen	0.1 mg L^{-1}	0.1 mg/L		0.1 mg/L	Field Measurement
Total suspended sediments	10 mg L^{-1}		4 mg/L	4 mg/L	2 mg/L
Conductivity/ salinity	1 -100 μS cm^{-1}	10 us/cm		10 us/cm	
Dissolved Organic Carbon	0.22 mg C L^{-1}	0.1 mg/L			
Dissolved inorganic carbon	3 mg C L^{-1}				
pH	0.01 pH	0.01 pH			
Particulate carbon	0.01%				
Photosynthetically active radiation (400 - 700 nm)	0.01 μmol s^{-2} m^{-2}				

VI. How Implemented Network Would Improve Ability to Address Management Issues

The United States Government Accountability Office (GAO) reported to Congress in April 2003 in response to a request from 14 members of Congress to (1) identify the federal and state programs operating in the Great Lakes Basin and the funding being devoted to them, evaluate how the restoration strategies are used and coordinated, and (3) assess overall environmental progress made in the basin restoration effort thus far.

There are 148 federal and 51 state programs funding environmental restoration activities in the Great Lakes Basin. Most of these programs involve the localized application of national or state environmental initiatives that do not specifically focus on basin concerns. GAO identified three principle findings: 1) Many federal and state programs fund restoration, as previously described; 2) Different strategies, lack of coordination, and limited funding impede restoration efforts; and 3) Insufficient data and measures prevent determination of overall restoration progress.

The information summarized in this report indicates that monitoring and assessment efforts currently being conducted in the Lake Michigan basin are adequate in some cases (but mostly in some local jurisdictions), but fairly inadequate on a lakewide scale, and in many cases, for some of the directly expressed needs of the National Monitoring Network for U.S. Coastal Waters and Their Tributaries. The Network could be thought of as the monitoring backbone to support coastal restoration efforts nationally. Specific examples from four of the Lake Michigan resource component groups are provided below.

However, the Network data must be made easily accessible in order for the implemented Network to improve our ability to address management issues. Having all the existing monitoring data available as GIS shapefiles will make a demonstration and implementation phase much easier. Some data sharing efforts are underway in the Great Lakes region are underway. In the Joint Strategic Plan for Management of Great Lakes Fisheries (1981, revised in 1997), U.S. and Canadian federal agencies and state, provincial, and intertribal agencies agreed to share data, particularly through compatible, automated information systems like Great Lakes GIS. Assuming that IOOS regions (GLOS in the Great Lakes region) help USGS, U.S. EPA and NOAA to prepare easily accessible shapefile coverage, our interagency ability to address management issues will be much improved.

Near Shore
Changes over the entire near shore, which are connected across state boundaries and cannot be assessed ad hoc by interspersed and limited efforts, is one component that the NMN has as an underlying objective to address. Such issues can get lost in the most myopic view.

Rivers
Without a continuous, consistent approach to monitoring rivers tributary to Lake Michigan it is not possible, with a high level of confidence, to know the trends in water quality. Without a complete understanding of trends it is difficult to know the impacts of management efforts or if there are new or emerging management issues. Lake Michigan is a drinking water source for 40 million people and one of the largest bodies of freshwater in the world and thus an important resource to protect.

Wetlands
In order to prevent additional impacts to coastal wetland resources, regulatory agencies with jurisdiction in coastal regions must develop tools to better assess the impacts that may be incurred due to development or alteration of coastal wetlands. Implementation of the three tiered NMN / U.S. EPA design would allow

agencies to collect valuable data that would unequivocally show whether Great Lakes coastal wetland area improving or deteriorating. Better regulatory decision making begins with the establishment of a baseline condition of the resource. Various management options can be better incorporated into the overall development plans for coastal watersheds if key functional wetlands can be identified. Wetland alteration resulting from permitting decisions would be better analyzed if ongoing monitoring of wetland resources allowed agencies to assess the existing conditions of wetland areas and predict functional losses if impacts were permitted.

Embayments

Despite their ecological importance to the Great Lakes as a whole, embayments are not currently afforded additional regulatory protections. Collection of monitoring data as described by the NMN design could help states realize the importance of these habitats as sentinel populations within the lakes, thus improving the managements of coastal watersheds.

VII. Relevance to IOOS

The Great Lakes Observing System Regional Association (GLOS-RA), a nonprofit corporation registered in the State of Michigan, is responsible for coordinating design, implementation and operation of a Regional Coastal Oceans Observing System (RCOOS) as part of the U.S. Integrated Ocean Observing System (IOOS) initiative. The GLOS-RA is a cooperative activity of many U.S. and Canadian federal and state/provincial agencies as well as academic institutions, nongovernmental organizations and commercial interests across the region. The Great Lakes Commission coordinated the initial development of GLOS, with funding provided by the Coastal Services Center of NOAA.

The focus of the design, implementation and operation of the GLOS-RCOOS is to meet critical information needs for priority issues that affect the health, ecological integrity and economic viability of the Great Lakes – St. Lawrence River region. Information to help address these priority issues would be generated through an integrated and systematic approach involving: installation and operation of new observational equipment and monitoring procedures; development of computer models that can better define complex physical, chemical and biological processes, coordination of existing information resources; and delivery of customized products to users through focused outreach and educational campaigns. The regional priority issues are consistent with the IOOS societal goals, which frame the conceptual design of the GLOS-RCOOS.

The GLOS-RCOOS would provide critical information not currently available that was identified by more than 1,500 representatives from federal, state and local agencies, academic, nongovernmental and Native American communities and private sector interests under the recent Great Lakes Regional Collaboration (GLRC). The GLRC is led by the U.S. Federal Great Lakes Interagency Task Force, which includes significant engagement from NOAA. The conceptual design for the GLOS-RCOOS also addresses some of the most pressing observing and monitoring shortfalls identified in recent reports from the U.S. GAO and within the Great Lakes Commission's Great Lakes Monitoring Inventory and Gap Analysis. These assessments reflect a broad political and scientific consensus on observing and monitoring needs of the region (GLOS-RCOOS Conceptual Plan 2008-2017).

The Data Management and Communications Plan of GLOS will serve as a blueprint and vehicle for implementing the data management and access recommendations of this Pilot Study. Rivers monitoring and specifically real time river monitoring will be an important addition to the GLOS-RCOOS. For further information on the GLOS, see the draft GLOS-RCOOS Conceptual Plan 2008-2017 at www.glos.us/about/RCOOS_ConceptualPlan.pdf.

VIII. Cost Estimates

Table 12. Cost estimates for Lake Michigan environmental components of the National Monitoring Network.

Environmental component	Annual cost of existing monitoring as specified by Network design	Annual incremental costs of monitoring needed to fill gaps	Annual cost of existing monitoring beyond Network design as determined by local needs and local experts	Incremental costs needed to bring extra monitoring to Network specifications
Embayments (Estuaries)	not determined	not determined	not determined	not determined
Near Shore	$83,520	unknown	unknown	unknown
Off Shore	<$1,000,000	low unknown	not determined	unknown
Rivers	$230,000 – Q* $200,000 – QW**	$0K – Q* $1.05M – QW**	$40,000 – Q* $30,000 – QW** at 3 sites	$0K – Q* $190,000 – QW** at 3 sites
Ground Water	$12,000	$135,500	$12,000	$0
Atmospheric Deposition	IADN - $800,000 States Hg - ? WDNR PCBs - ?	Hg - $200,000 start-up and $100,000 per year Passive sampling - $50,000 per year New chemicals - $100,000 per year	not determined	not determined
Wetlands	unknown	$800,000	unknown	unknown
Beaches	$780,000	$7,695,000	$9,022,800	$2,528,400

* = Discharge
** = Water Quality

Cost Estimate Notes

Near Shore

Cost is for State of Illinois Lake Michigan monitoring program, the only actual "near shore" monitoring numbers available. The cost figure is for 21 near shore stations. IL is currently looking into the possibility of getting its own boat and revamping their Lake Michigan program. They will continue with some near shore sampling (it may not be the same number/location they are currently doing) in addition to sampling harbors, river/stream mouths, etc.

Off Shore

GLNPO's annual monitoring budget was estimated as 4.5 million in 1992 and 4.7 million in 2007. Divided by five lakes, this is less than $1,000,000 per lake.

Rivers

Currently about $500,000 is being spent to monitor water quality and quantity at the 20 proposed Lake Michigan network sites. It would cost another $1,200,000 to fill the monitoring gaps at these 20 sites.

Ground Water
Some of the ground water monitoring can be coordinated with beach monitoring efforts for the direct component of shallow ground water discharge to Lake Michigan.

Breakdown of costs for ground water:

1. Sample 5 existing wells = $5,000 lab costs, $6,000 travel and labor, $1,000 QA/QC and data base
2. Drill and install 32 wells at 20 locations = $85,000 (includes labor and materials)
3. Sample 32 new wells = $20,000 lab costs, $12,000 travel and labor, $6,500 QA/QC and data base
4. Apply flow model assessments to water-quality data and report analysis = $12,000

Wetlands
Assumption that monitoring partners would all have two staff devoted to each sampling component (chemistry, fish, landscape, etc), that all agencies would have all necessary equipment and that a total of 70 wetlands would be sampled in Lake Michigan.

Beaches
The current annual cost for monitoring Lake Michigan beaches is at least $780,000. This amount is based on federal grants allocated for Illinois, Indiana, Michigan, and Wisconsin. The frequency of monitoring and percentage of beaches monitored varies among states. Illinois monitors between five and seven times per week at 54 of their 73 beaches on Lake Michigan. Indiana monitors between five and seven times per week at all 25 of their beaches on Lake Michigan. Michigan monitors once per week at 110 of their 299 beaches on Lake Michigan. Wisconsin monitors between two and seven times per week at 79 of their 147 beaches on Lake Michigan.

The annual incremental cost of monitoring needed to fill the gaps is $7,695,000. This amount is based on additional costs to conduct beach sanitary surveys at monitored beaches at a cost of $5,000 per beach, to monitor all beaches on Lake Michigan, and to develop a predictive model for one-third of the monitored beaches at a cost of $50,000 per model.

The annual cost of existing monitoring beyond the Network design as determined by local needs and local experts is $9,022,800. This amount is based on additional costs to have 10 beaches per state use a rapid test method (Quantitative Polymerase Chain Reaction, (QPCR)) to conduct beach sanitary surveys for half of the beaches that are not currently monitored and to develop a predictive model for remaining monitored beaches at an estimated cost of $30,000 per model. This estimate for the model is based on the assumption that costs would be reduced as models become easier to implement and manage.

The incremental cost needed to bring extra monitoring to Network Specifications is $2,528,400. This amount is based on additional costs to have all currently monitored beaches use a rapid test method (Quantitative Polymerase Chain Reaction, (QPCR).

IX. Summary and Major Conclusions from Pilot Study

In spite of their large size, the Great Lakes are sensitive to the effects of a wide range of pollutants from permitted discharge, urban and agricultural run-off, leachate and ground water. The large surface area of the lakes also makes them vulnerable to direct atmospheric pollutants, transported by weather that falls with rain snow or dust from extreme distances. Outflows from the Great Lakes are relatively small (less than 1 per cent per year) in comparison with the total volume of water. Pollutants that enter the lakes are retained and recycled in the system and can become more concentrated with time.

Although part of a single system, each lake is different. Because of the large size of the watershed, physical characteristics such as climate, soils and topography vary across the basin. To the north, the climate is cold and the terrain is dominated by granite bedrock called the Canadian or Laurentian shield consisting of Pre-Cambrian rocks under a generally thin layer of acidic soils. Conifers dominate the northern forest. In the southern areas, the climate is warmer with deeper soils developed on a variety of sediments deposited by glaciers and as lakes, beaches, outwash plains, wetlands and streams. In addition, there are over 30,000 islands and very large bays (Green Bay, Grand Traverse Bay, Saginaw Bay, Georgian Bay) that are also unique in how pollutants are processed in the sub-bay system thus requiring special or additional sampling.

As receiving bodies of tributaries which are, in turn, receiving bodies for industrial and agricultural discharges, the lakes also serve as drinking water for 40 million people. As the only fresh coast of the United States, the lakes provide recreation through fishing, boating, and the world's largest collection of freshwater sand dunes. Biological monitoring is important not only from an ecosystem perspective but also for public health. Monitoring and research for the last six years has begun to show a great contrast between the near shore and the open lake. This also varies by lake but we see almost two separate systems within each lake basin providing another monitoring complexity.

Monitoring currently being conducted does not fully meet the Network design in any of the resource component groups. In some components (i.e. Rivers, Atmospheric Deposition) the current monitoring locations are similar to the proposed design. In other resource components (i.e. Beaches) the constituents proposed for the Network design are currently being sampled. In other resource component groups (i.e. Groundwater, Atmospheric Deposition, Rivers) the temporal approach proposed in the design is for the most part being met. Monitoring protocols being used across the resource components are comparable across the various monitoring entities in some cases but not in all cases; and these protocols do not in all cases meet the Network design requirements. QA/QC activities across most of the resource component groups meet the NMN design requirements; however, this is not true for all of them. Data management approaches are not fully integrated for any of the resource components, however, for some components (i.e. Beaches, Atmospheric Deposition, Off Shore) coordinating data management will be easier than for others (i.e. Near Shore, Wetlands). The cost of filling the monitoring gaps varies considerably across the various resource components, from several hundred thousand dollars to close to ten million dollars. The total monitoring gap for the Lake Michigan Pilot Study is in the neighborhood of $25 million.

Finally, even if the NMN is implemented as designed, we still would need to compare the data to benchmarks before we could identify the condition of the resource and know whether additional protective measures are needed. As an example, the CDC's National Health and Nutrition Examination Survey can detect hundreds of chemicals in human tissue, but we don't know whether certain contaminant concentrations are harmful or not.

Appendices

Appendix 1.

The first column is from column 1 of "Table 3-1 Network measurements" in the Network design report (p. 23). The top row includes eleven subgoals from the 2000 Lake Michigan Lakewide Management Plan (LaMP). The second row associates one or more of the 14 beneficial use impairments listed in Annex 2 of the Great Lakes Water Quality Agreement of 1978 As Amended by Protocol Signed November 18, 1987: i) restrictions on fish and wildlife consumption; ii) tainting of fish and wildlife flavor; iii) degradation of fish wildlife populations; iv) fish tumors or other deformities; v) bird or animal deformities or reproduction problems; vi) degradation of benthos; vii) restrictions on dredging activities; viii) eutrophication or undesirable algae; ix) restrictions on drinking water consumption, or taste and odor problems; x) beach closings; xi) degradation of aesthetics; xii) added costs to agriculture or industry; xiii) degradation of phytoplankton and zooplankton populations; and xiv) loss of fish and wildlife habitat. The remaining rows are not all complete, and the table remains a work in progress. Ideally, the completed table would identify the type of physical, chemical, and biological monitoring needed to evaluate progress in delisting Areas of Concern with Annex 2 beneficial use impairments and lakewide impairments. Monitoring activities identified through the Lake Michigan Pilot can be used to fill in the blanks, but some table cells will remain blank.

Alignment of National Monitoring Network Network Measurements with the Lake Michigan Lakewide Management Plan Subgoals and GLWQA Annex 2 Beneficial Uses

Monitoring category	**We can all eat any fish.**	**We can drink the water.** Contaminants are from Drinking Water Standards and Health Advisories, http://www.epa.gov/waterscience/criteria/drinking/dwstandards.pdf	**We can swim in the water.**	**All habitats are healthy, naturally diverse, and sufficient to sustain biological communities.**	**Public access to open space, shoreline, and natural areas is abundant and provides enhanced opportunities for human interaction with the Lake Michigan ecosystem.**	**Land use, recreation, and economic activities are sustainable and support a healthy ecosystem.**	**Sediments, air, land, and water are not sources or pathways of contamination that affect the ecosystem.**	**Exotic species are controlled and managed.**	**Ecosystem stewardship activities are common and undertaken by public and private organizations in communities around the basin.**	**Collaborative ecosystem management is the basis for decision-making in the Lake Michigan Basin.**	**We have enough information/ data/ understanding/ indicators to inform the decisionmaking process.**
1987 GLWQA Annex 2 Beneficial Use Impairments->	**(i) and (ii)**	**(ix)**	**(x)**	**(iii), (iv), (vi), (viii), (xiii), (xiv), and (v)**	**(xi)**	**(vii) and (xii)**					
Physical											
Flow magnitude and direction (stream, ground water, seiche, currents, wind)	See habitat subgoal.	See habitat subgoal.	need probabilistic model input	need pumping & water level data to protect surface water habitat			need flow to calculate loads				need
Physical habitat (channel slope, width, bottom materials, depth)	See habitat subgoal.	See habitat subgoal.	turbidity/transparency	needed for 303(d)/305(b) list/report							need data

Sediments (suspended, bottom, grain size)	See habitat, pathway, and exotic species subgoals.	See habitat subgoal.		needed for 303(d)/305(b) list/report					Communities have to be educated about stormwater; tracking and erosion ordinances have to be enforced		need
Chemical---inorganic											
Water-quality characteristics (temp., pH, DO, cond., turbidity, color, alkalinity)	See habitat and exotic species subgoal.	pH, odor, turbidity, color, corrosivity, foaming agents, total dissolved solids	need turbidity or transparency data; pH near cement kiln dust wastepiles, maybe others	needed to assess habitat	some recreational shoreline impaired by high pH		need		citizen monitoring develops sense of stewardship		need
Major ions (Ca, Mg, K, Na, Cl, SO4)	See habitat subgoal.	sodium, chloride, cyanide, fluoride, sulfate, bromate, chloramine (as free Chlorine), chlorine dioxide, chlorite,									need
Nutrients (No2, NO3, NH4, Org N, P, Si)	See habitat subgoal.	Ammonia, Nitrate (as N), Nitrite (as N), Nitrate + Nitrite (both as N)		needed to assess habitat			nutrients could be an indicator of algal transport of contaminants?		need		need
Metals and metalloids (Al, As, Cd, Cr, Cu, Fe, Pb, Hg, Se, Zn)	See habitat subgoal. FDA guidelines for Arsenic; Cadmium; Chromium; Lead; Nickel; Methyl Mercury	aluminum, antimony, arsenic, asbestos, barium, beryllium, boron, cadmium, chromium (total), copper (at tap), iron, lead (at tap), manganese, mercury (inorganic), molybdenum, nickel, selenium, silver, strontium, thallium, zinc, radionuclides (beta particle and photon activity, gross alpha particle activity, combined radium 226 & 228, radon, uranium)					need to define extent of contamination				need
Chemical---organic											
Carbon (total, dissolved, org., inorg.)	See habitat subgoal.										need

Bulk organics (oil and grease, humic and fulvic acids)	Acenaphthene, Monochlorobenzene, Chlorophenols, Dichlorophenols, Copper, Methylchlorophenols, 2,4-Dimethylphenol, Hexachloropentadiene, Nitrobenzene, Pentachlorophenol, Zinc cause organoleptic effects.	Acenaphthene, Monochlorobenzene, Chlorophenols, Dichlorophenols, Copper, Methylchlorophenols, 2,4-Dimethylphenol, Hexachloropentadiene, Nitrobenzene, Pentachlorophenol, Zinc cause organoleptic effects.			oil sheens detract from recreational experience		Need to define extent of PCB and dioxin contamination		need		need
VOCs (some of these could also be in halogenated hydrocarbons and in pesticides)	See habitat subgoal.	Carbon Tetrachloride, Ethylbenzene, Methyl ethyl ketone, Tetrachloroethane (1,1,1,2-), Tetrachloroethane (1,1,2,2-), Tetrachloroethylene, Trichlorofluoromethane, Toluene, Trichlorobenzene (1,2,4-), Trichlorobenzene (1,3,5-), Trichloroethane, (1,1,1-), Trichloroethane (1,1,2-), Trichloroethylene, Trichlorophenol (2,4,6-), Trichloropropane (1,2,3-), Trifluralin, Trimethylbenzene (1,2,4-), Trimethylbenzene (1,3,5-), Trinitroglycerol, Trinitrotoluene (2,4,6-), Vinyl Chloride, xylenes, MtBE?	Are VOCs ever high enough in lake water to pose dermal or inhalation risks?				does contaminated groundwater discharge to streams at environmentally significant concentrations?				need
Pesticides (aldrin, dieldrin, DDT, DDD, DDE, chlordane, hexachloro-benzene, mirex, atrazine, simzine, alachlor, aldicarb)	See habitat and pathway subgoal. 1990s, the FDA identified risk-based action levels for these contaminants in fish: Aldrin/Dieldrin; Benzene hexachloride; Chlordane; Chordecone; DDT, TDE, and DDE; Diquat; Fluoridone; Glyphosate; ; Heptachlor/Heptachlor Epoxide; Mirex; Simazine; and, 2,4-D (on a limited basis).	Acifluorfen (sodium), Acrylamide, Acrylonitrile, Alachlor, Aldicarb, Aldicarb sulfone, Aldicarb sulfoxide, Aldrin, Ametryn, Ammonium sulfamate, Atrazine, Baygon, Bentazon, bis-2-Chloroisoproplyl ether, Bromacil, Bromobenzene, Bromochloromethane, Bromodichloromethane (THM), Bromoform (THM), Bromomethane, Butyl benzyl phthalate, Butylate, Carbaryl, Carbofuran, Carboxin, Chloramben, Chlordane, Chloroform (THM), Chloromethane, Chlorophenol (2-), Chlorothalonil, Chlorotoluene (o- and p-), Chlorpyrifos, Cyanazine, Cyanogen chloride, 2,4-Dichlorophenoxyacetic acid (2,4-D), Dacthal (DCPA), Dalapon (sodium salt), di(2-ethylhexyl)adipate, Di-(2-ethylhexyl)phthalate, Diazinon, Dibromochloromethane (THM), Dibromochloropropane (DBCP), Dibutyl phalate, Dicamba, Dicholoroacetic Acid, Dichlorobenzene (o-, m-, p-), Dichlorodifluoromethane, Dichloroethane (1,2-), Dichloroethylene (1,1-), Dichloroethylene (1,1-), Dichloroethylene (1,1-), Dichloroethylene (cis-1,2), Dichloroethylene (trans-1,2-), Dichloromethane, Dichlorophenol (2,4-), Dicholoropropane (1,2-), Dichloropropane (1,3-), Dieldrin, Diethyl phthalate, Diisopropyl methylphosphonate, Dimethrin, Dimethyl methylphosphonate, Dimethyl phthalate, Dinitrobenzene (1,3-), Dinitrotoluene (2,4-), Dinitrotoluene (2,6-), Dinitrotoluene (2,6- & 2,4-), Dinoseb, Dioxane-p, Diphenamid, Diquat, Disulfoton, Dithiane(1,4-), Diuron, Endothall, Endrin, Epichlorohydrin, Ethylene dibromide (1,2-	Are pesticide concentrations ever high enough to pose risk?	needed to protect habitat			Sources have to be controlled or eliminated		need		

		dibromoethane), ethylene glycol, Ethylene Thiourea, Fenamiphos, Fluormeturon, Fonofos, Formaldehyde, Glyphosate, Heptachlor, Heptachlor epoxide, Hexachlorobenzene, Hexachlorobutadiene, Hexachlorocyclopentadiene, Hexachloroethane, Hexane (n-), Hexazinone, HMX (octahyrdro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine), Isophorone, Isopropyl methylphosphonate, Isopropylbenzene (cumene), Lindane (gamma-hexachlorocyclohexane), Malathion, Maleic hydrazide, MCPA (4(chloro-2-methoxyphenoxy)acetic acid), Methomyl, Methoxychlor, Methyl Parathion, Metolachlor, Metribuzin, Monochloroacetic acid, Monochlorobenzene, Nitroguanidine, Nitrophenol-p, Tebuthiuron, Terbacil, Terbufos, Toxaphene, 2,4,5-TP (Silvex), Metolachlor, Metribuzin, Oxamyl, Paraquat, Pentachlorophenol, Phenol, Picloram?, Prometon, Pronamide, Propachlor, Propazine, Propham, RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine), Simazine, 2,4,5-T (Trichlorophenoxy-acetic acid)									
Halogenated hydrocarbons (PCBs, dioxins/furans)	FDA & State guidelines for Polychlorinated Biphenyls; MDCH trigger level for dioxin TEQs	2,3,7,8-TCDD, Trichloroacetic acid, Monochloroacedtic acid, Monochlorobenzene, Polychlorinated biphenyls,	High enough to pose risk?				Extent of contaminantion must be understood to control contamination				need
PAHs (naphthalene, phenanthrene, pyrene, benzo(a)pyrene)		Acenaphthene, Anthracene, Benz[a]anthracene, Benzo[b]fluoranthene, Benzo[g,h.i]perylene, Benzo[k]fluoranthene, Chrysene, Fluorene, Indeno[1,2,3,-c,d,]pyrene, Naphthalene, Phenanthrene, Pyrene, Styrene?	High enough to pose risk? Maybe in IHC, Calumet?	need to monitor habitat (causes deformities, lesions, tumors)	fish deformities detract from recreational experience		are sources adequately controlled? Can't tell without monitoring		need		need
New and emerging contaminants (PPPCP, antibiotics, BDEs, PFOS, lube(s)/additives, surfactants)	See habitat and pathway subgoal.		High enough to pose risk?	need to evaluate risk to organisms in environment	unnatural foaming detracts from the recreational experience				need		need
Biological											
Biological assessments (chl a, algae, bacteria, viruses, macroinvertebrates, fish)	Botulism toxin? See habitat, exotic species, and pathway subgoals	Pathogens (Cryptosporidium, Giardia lamblia, Legionella, Heterotrophic Plate Count, Mycobacteria, Total Coliforms, Viruses), algae toxins	Pathogens (Cryptosporidium, Giardia lamblia, Legionella, Heterotrophic Plate Count, Mycobacteria, Total Coliforms, Viruses), toxic algae	need to assess biological integrity	algal blooms, anoxic conditions, dead fish, decaying algae, and illnesses from direct contact with pathogens detract from recreation		need		need		need

Appendix 2. The top ten, highest priority issues for monitoring Great Lakes beaches, and actions that have been taken to address them (to date):

1. *Affordable Rapid Methods:* Rapid test methods for measuring beach water quality are being evaluated through the USEPA and the Center for Disease Control and Prevention (CDC) National Epidemiological Environmental Assessment of Recreational (NEEAR) Waters Study. Rapid test methods are also being evaluated by the Southern California Coastal Water Research Project (SCCWRP).

2. *Predictive Models:* Illinois, Indiana, Wisconsin, U.S. EPA, NOAA, and USGS developed forecasting models for several Lake Michigan beaches. The models predict when a beach should be open or closed due to bacterial contamination. Similar forecasting models are being developed for Lake Michigan beaches in Michigan. *Statistical Framework for Recreational Water Quality Criteria and Monitoring (Statistics in Practice)* by Larry J. Wymer (editor) was published in November, 2007 and has 11 chapters with contributions from 18 experts.

3. *Real-time Data:* Increased accessibility to water temperature data is being provided by NOAA. The BeachCast website provides Great Lakes beachgoers with access to information on beach conditions, including health advisories, water temperature, wave heights, and monitoring data.

Developing new technological approaches, including the use of available real time sensors in a number of resource components as surrogates for indicators and pathogens, may provide a means to minimize the cost of information collection needed to refine models and meet beach management needs.

4. *Source Tracking Tools:* The journal, *Water Research*, published several articles in the August, 2007 issue entitled, "Identifying Sources of Fecal Pollution," Volume 41, Issue 16, Pages 3515-3792. This issue included two review articles and 24 full papers. U.S. EPA published the *Microbial Source Tracking Guide Document* in June 2005. The report is available at http://www.epa.gov/nrmrl/pubs/600r05064/600r05064.pdf.

Source and fate studies are being conducted by USGS, U.S. EPA, and NOAA via the Center of Excellence for Great Lakes and Human Health research team at Michigan State University to identify non-fecal, nonpoint indicator bacteria sources. Background levels of indicator bacteria and non-fecal sources are being identified.

Soil and runoff input of fecal bacteria are being characterized in coastal streams and waterways by USGS.

U.S. EPA has all of the stormwater outfall locations that the states have entered into the Permit Compliance System (PCS) national database. A subset of these data, CSO, has been previously mapped for the Great Lakes basin. However, because the PCS database is regularly updated by the states, it would be prudent to conduct a new mapping effort using the most updated outfall locations should the need arise.

U.S. EPA has developed Geologic Information System (GIS) maps of Great Lakes tributaries, has the most up-to-date hydrological GIS data from USGS, and has generated maps for many of the Great Lakes Tributaries.

5. *Epidemiological Data:* Studies of new pathogen indicators are being conducted through the NEEAR Waters Study as required by the BEACH Act. Based on the results of the NEEAR Waters Study, U.S. EPA will develop new ambient water quality criteria for coastal and Great Lakes waters. These criteria will take advantage of the new rapid indicator methodology and advanced state of the science of health implications from recreational waters.

U.S. EPA and the CDC hosted the "Workshop for Improving Waterborne Outbreak Surveillance, Investigations and Reporting" in June 2007. Discussions included waterborne outbreaks from drinking water sources and recreational water sources. U.S. EPA published the *Report of the Experts Scientific Workshop on Critical Research Needs for the Development of New or Revised Recreational Water Quality Criteria*, in June 2007.

6. *Training:* A Beach 101 class has been added to the GLBA Annual Conference and National Beaches Conference. The Beach 101 class has been attended by approximately 40 people each year. This class provides introductory information for beach monitoring programs.

The Illinois Department of Public Health, U.S. EPA, and USGS developed a training video on the use of predictive models of high bacteria levels to better inform the public of the status of beach water quality. The video explains several different types of predictive models and will train beach management personnel on how to collect and interpret predictive modeling data.

A video to train individuals on how to conduct water quality sampling at beaches was developed by the Wisconsin Department of Natural Resources. The video is posted on the Wisconsin State Laboratory of Hygiene's web page at http://www.slh.wisc.edu/wps/wcm/connect/extranet/ehd/pamphlets/index.php.

Beach management workshops are held annually by the GLBA at various locations around the Great Lakes. The 6th annual GLBA conference was in Niagara Falls, New York in October 2006, in conjunction with the National Beach Conference. The 7th annual GLBA conference was held in Traverse City, Michigan in October 2007 in conjunction with the State of Lake Michigan Conference.

Several Great Lakes states host beach management workshops and promote conferences and newsletters via the Beachnet listserv and U.S. EPA's BEACH Watch web site. Information and announcements are also posted in U.S. EPA's quarterly *Beach Currents Newsletter* which is available on the BEACH Watch web site.

The Center for Water Sciences at Michigan State University hosted a Pathogen Workshop Series in 2007. Nine experts prepared white papers and gave presentations on waterborne pathogens, harmful algal blooms, source tracking, pathogen transport, and predictive models. Lectures were webcasted live and are available at http://cws.msu.edu/pathogen_wkshop.htm.

7. *Standardized Beach Sanitary Surveys:* U.S. EPA in collaboration with members of the GLBA, developed a standardized sanitary survey in 2006 for use by all Great Lakes beach managers for the identification of contamination sources impacting beaches. A federal grant of $500,000 was provided by U.S. EPA for pilot studies in 2007 for beach sanitary survey projects on Great Lakes beaches. Lake Michigan beaches in Wisconsin, Illinois, and Michigan received funding. Results from the pilot studies were discussed at the State of Lake Michigan-GLBA Conference in October, 2007. Written reports of the pilot studies will be available in 2008. The beach sanitary survey project was the first recommendation of the Great Lakes Regional Collaboration Coastal Health Strategy to receive funding.

8. *Standardized Monitoring Protocols:* U.S. EPA published *The EMPACT Beaches Project: Results from a Study on Microbiological Monitoring in Recreational Waters* in June, 2005. The report is available at http://www.epa.gov/nerlcwww/empact.pdf.

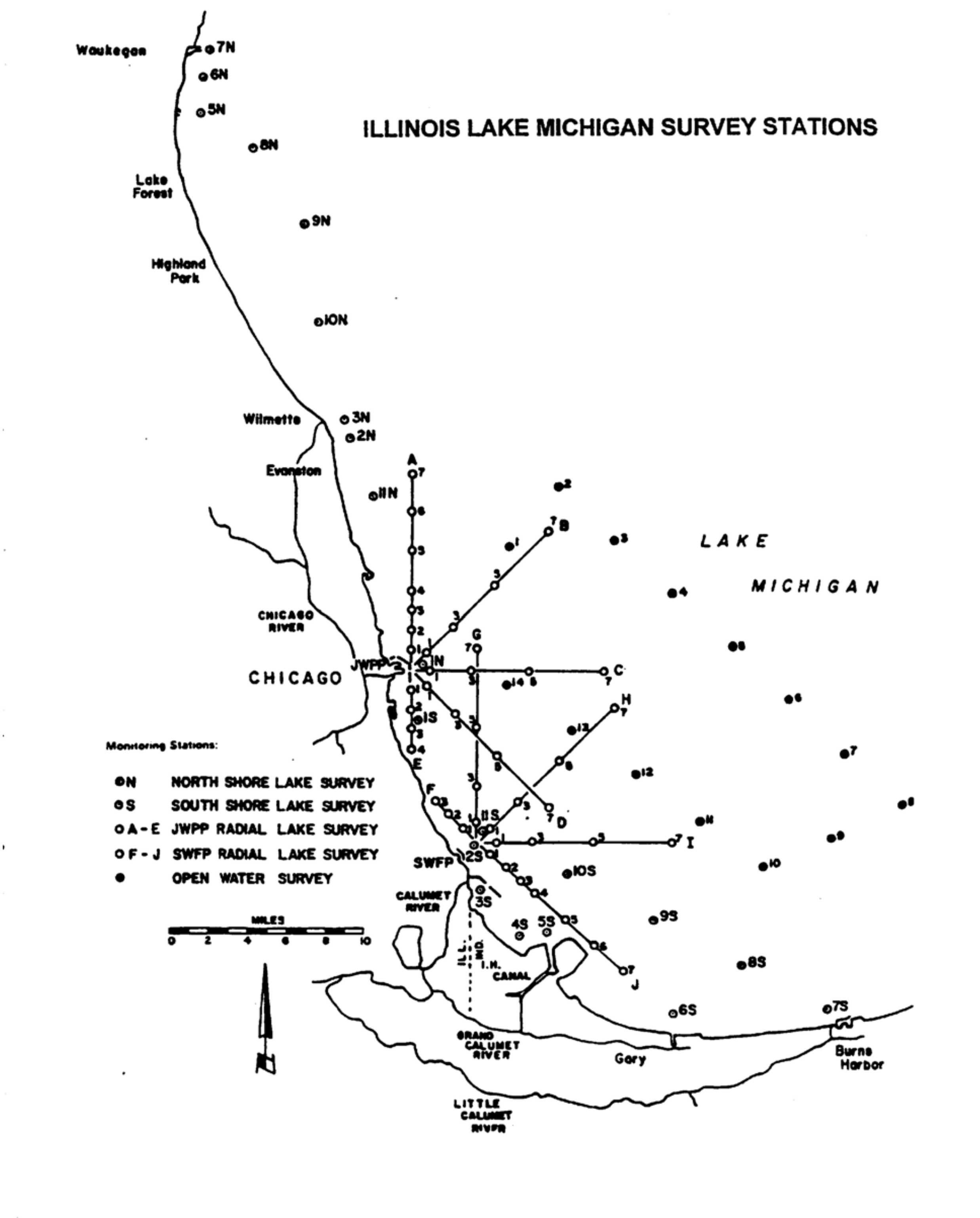
9. *Better Communication Among Agencies:* The USGS-GLSC, the GLBA, and the Great Lakes Information Network host The Beach Network (http://www.beachnet.info/), a web site dedicated to improving beach management through communication.

Information is shared regularly via listservs. The BeachNet listserv facilitates communication among 600 beach managers and experts interested in the improvement of recreational beach water quality. U.S. EPA maintains the Beachinfo listserv for state beach coordinators and EPA staff. NOAA-GLERL hosts the HABS listserv for topics related to harmful algal blooms. The NOAA Center of Excellence for Great Lakes and Human Health and several states developed beach health outreach products with advice for beachgoers on how to help keep beach water clean to reduce the risk of contracting illness at beaches.

10. *Assistance with Determining Health Risks from Natural Elements:* The University of Wisconsin-Oshkosh hosted a meeting in January 2008 entitled "Cladophora in the Great Lakes: State of the Research."

Appendix 3. Illinois Fixed Monitoring Locations

(Note: Station location and frequency of sampling are provided in Appendix 8 of IEPA's monitoring strategy.)



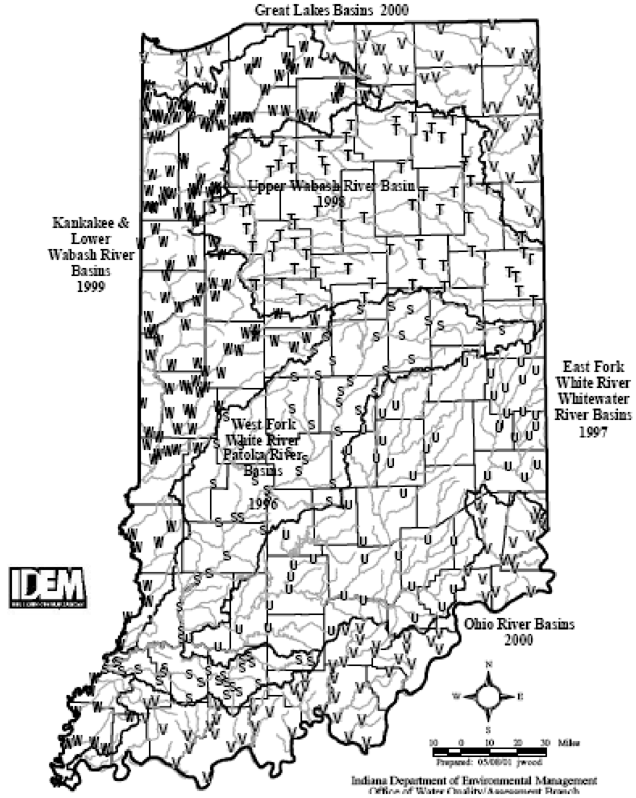
Appendix 4. Indiana Monitoring Locations

Fixed Station Surface Water Quality Program

Monthly Monitoring Sites 1999 To Present

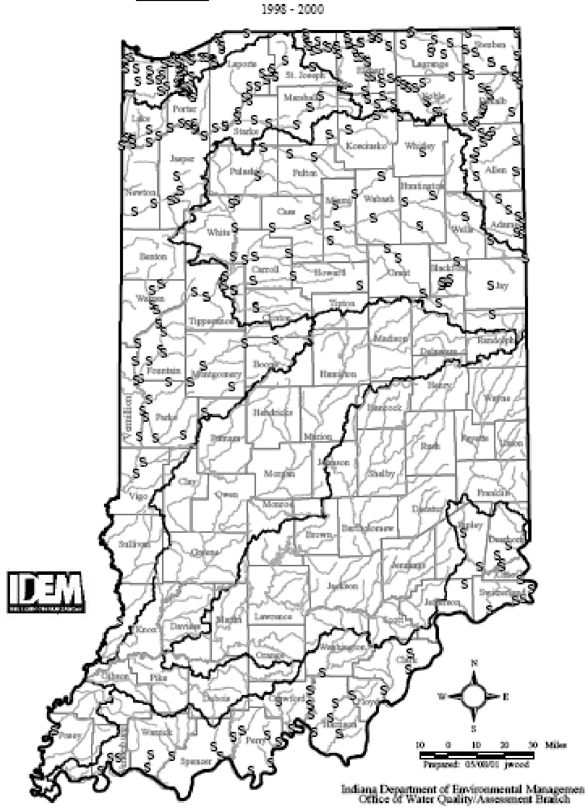
Watershed Monitoring Program

Great Lakes Basins 2000



E. coli **Monitoring Program**

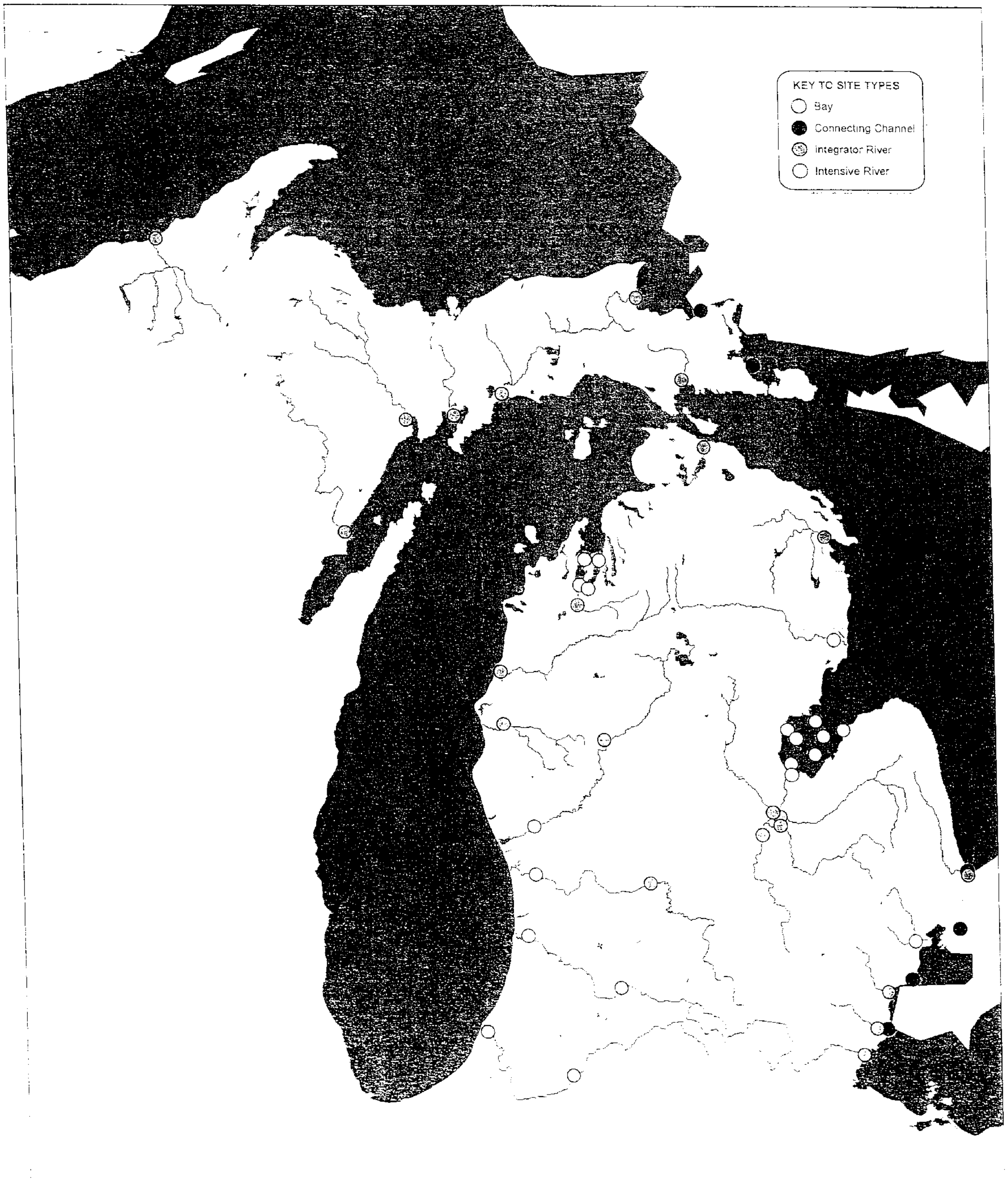
1998 - 2000



Appendix 5. Michigan Fixed Monitoring Locations

Figure 5

Water chemistry trend monitoring locations in Michigan
(Bay, Connecting Channel, Intensive, and Integrator types).



Appendix 6. Wisconsin Fixed Monitoring Locations

Popple R. at Fence, Wolf R. at Langlade, Menominee R. at McAllister, Peshtigo R. at Peshtigo, Oconto R. at Oconto, Wolf R. at New London, Fox R. at DePere, Fox R. at Neenah & Menasha, Fox R. at Berlin, Fox R. at Oshkosh, Kewaunee R. at Kewaunee, Manitowoc R. at Manitowoc, Sheboygan R. at Esslingen Park, Milwaukee R. at Estabrook Park, Root R. at Johnson Park.

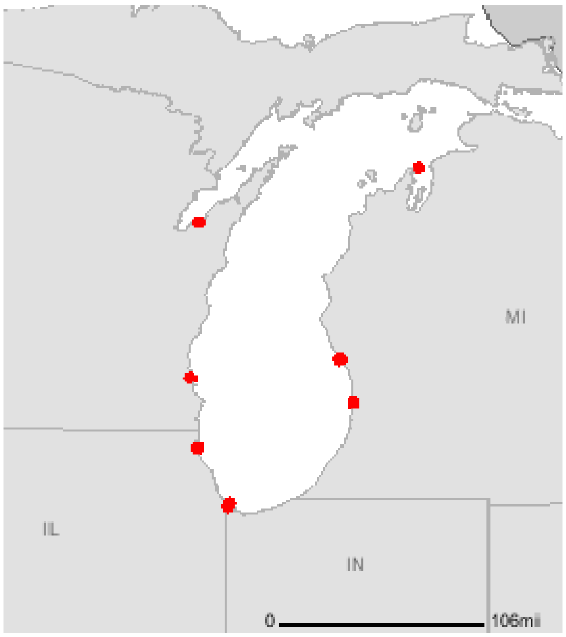
Figure 2. Long Term Trend/Ambient Water Quality Monitoring stations and drainage area

Wisconsin Department of Natural Resources Water Division (http://dnr.wi.gov/org/water/monitoring/MonitoringStrategyV2.pdf)

Appendix 7. Mussel Watch Monitoring Locations (latitude, longitude)

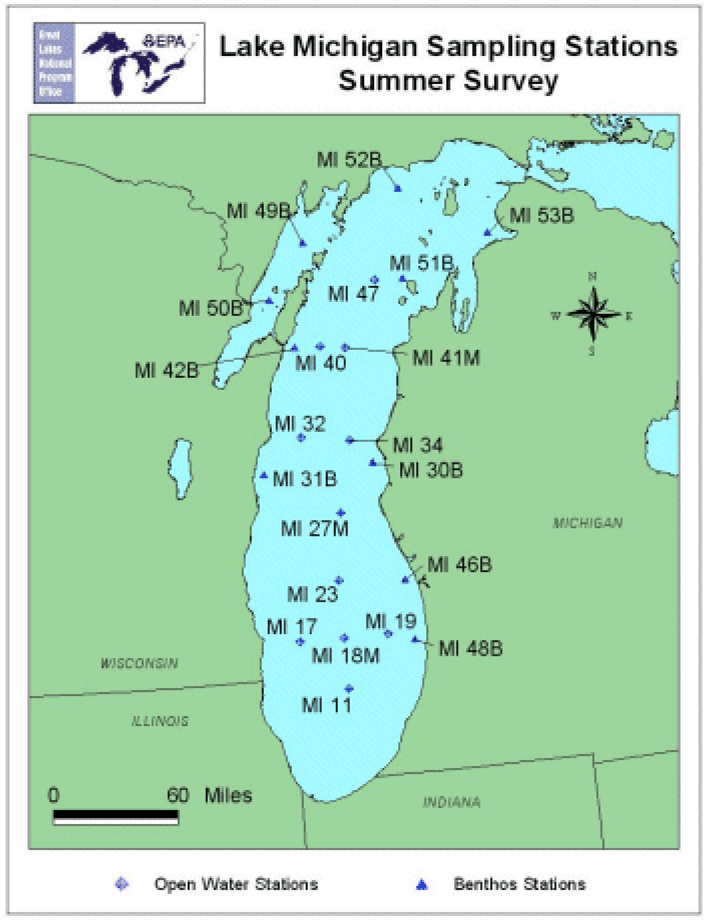
Hammod Marina, Indiana 41.69865, -87.50825
Calumet Breakwater, Illinois/Indiana 41.72716667, -87.495
North Chicago, Illinois 42.3055, -87.82783333
Milwaukee Bay, Wisconsin 43.032166667, -87.89516667
Bayshore Park, Green Bay, Wisconsin,44.50466667 -87.79666667

Leelanau Bay State Park, Traverse Bay, 45.205666667, -85.53683333
Muskegon, Michigan 43.225833333, -86.347
Holland Breakwater, Michigan 42.77383333, -86.21466667



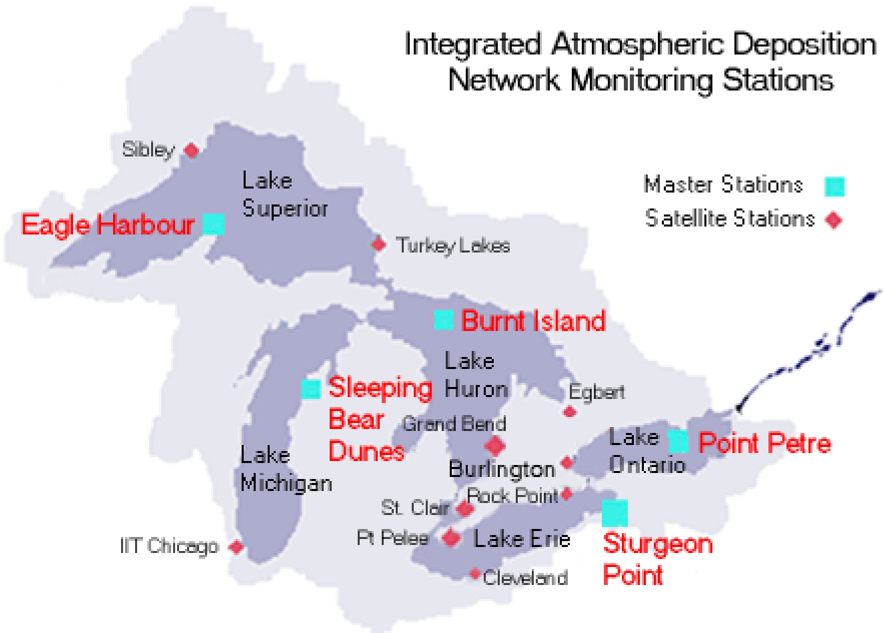
Appendix 8. U.S. EPA GLNPO Monitoring Locations for Air, Fish, Limnology, and Sediment

Limnology



http://www.epa.gov/glnpo/monitoring/limnology/Station_Maps/Michigan_stations.html

Appendix 9. Integrated Atmospheric Deposition Network Monitoring Stations



http://www.msc-smc.ec.gc.ca/iadn/stations/station_master_e.html

Appendix 10. Mercury Trends Network of the National Atmospheric Deposition Program

Monitoring Atmospheric Mercury Species and Mercury Wet Deposition Events

The proposed Mercury Trends Network (MTN), to be implemented through the National Atmospheric Deposition Program (NADP), will immediately establish a national network of monitoring stations in the United States. The Mercury Trends Network will be an intensively operated subset of the NADP-MTN, collocated where possible with stations from other national atmospheric monitoring networks. At each MTN station, the following data will be collected: event-based concentrations of total mercury in precipitation samples; concentrations of atmospheric mercury species from continuous-automated and proposed manually-operated measuring systems; and meteorological measurements for computing mercury wet deposition and estimating mercury dry deposition. Data will be collected with standardized methods developed through USEPA research, quality-assured, and archived in the NADP on-line data base.

Key Objectives

- Determine the status and trends in:
    - regional concentrations of ambient mercury species (reactive gaseous, particulate-bound, and elemental);
    - regional estimates of dry deposition of mercury;
    - regional total deposition of atmospheric mercury (wet plus dry).
- Represent areas with the highest mercury emissions and highest mercury wet deposition for the status and trends in concentrations of atmospheric mercury species and total deposition of atmospheric mercury.
- Represent other areas of the U.S. that will provide the baseline data necessary for mercury modelers to improve their modeling capabilities and further understanding of mercury in the atmosphere and dry depositing to the surface.

Approach

The MTN will begin operation in early 2007 with sponsors and participants coordinated through the structure and organization of the NADP. The MTN will include national monitoring locations that are regionally representative; rural, urban, and suburban; areas with high levels of mercury emissions and mercury deposition; and sensitive ecosystems. Monitoring will include mercury in precipitation, atmospheric mercury, and meteorological data. Daily values of atmospheric mercury species concentrations, mercury wet deposition, and mercury dry deposition at the monitoring stations will be archived in the NADP on-line data base. Maps and charts will be posted showing quarterly and annual estimates of the total deposition of atmospheric mercury. All monitoring data will be stored in a centralized data base. Standard procedures for network operation, quality assurance, and data management will be documented and managed by an NADP steering committee.

The NADP's Role

The NADP will have a very specific role in the operation of the transition network and on into the proposed full network. The role we can play is simply organization that will produce data that are accessible, good quality, and comparable throughout the MTN. Specifically, NADP will:

- coordinate the network through the established, open, collaborative NADP process,
- produce sampling and analysis standard operating procedures for network operation,
- produce quality assurance procedures and auditing services to provide confidence and consistency in network data,
- provide data management for consistent data validation, while providing multi-station data in a public forum for further research and modeling efforts

Appendix 11. Trace Metals, Metaloids, and Organic Compounds

	Analytes In:							
	Analyte	CAS Numbers Below Denote Contaminants Listed in The National Toxics Rule	Water	Fish Tissue	Sediment	Atm Dep Master Stations	Atm Dep at Some Stations	Atm Dep Loadings Available
	gross alpha and beta radioactivity		IN					
Trace Metals and Metaloids								
	Aluminum	7429-90-5	IN,IL,GLNPO	**MW**	**X**			
	Antimony	7440-36-0		**MW**	**X**			
	Arsenic	7440-38-2	**IN, IL,GLNPO**	**MW**	**IL**			**X**
	Barium	7440-39-3	**IN,IL,WI,GLNPO**		**IL**			
	Beryllium	7440-41-7	**IL, GLNPO**					
	Boron	7440-42-8	**IL,GLNPO**					
	Cadmium	7440439	**IN,IL,MI,WI,GLNPO**	**MW**	**IL**		**X**	**X**
	Calcium	7440-70-2	**IN,IL,GLNPO**				**X**	
	Cesium	10045-97-3	**GLNPO**					
	Chromium	7440-47-3	**IN,IL,MI,WI,GLNPO**	**MW**				
	Chromium III	16065831	**X**	**X**	**X**			
	Chromium IV (do you mean +6)	18540299	**IN Cr+6 7440-47-3**	**X**	**X**			
	Cobalt	7440-48-4	**IL,GLNPO**					
	Copper	7440-50-8	**IN,IL,MI,WI,GLNPO**	**MW**	**IL**			
	Iron	7439-89-6	**IN,IL,GLNPO**	**X**	**IL**			
	Lead	7439-92-1	**IN,IL,MI,GLNPO**	**MW**	**IL**			**X**

	Lithium	7439-93-2		GLNPO				
	Magnesium	7439-97-6	**IN,IL,WI,GLNPO**				**X**	
	Manganese	7439-96-5	**IN,IL,WI,GLNPO**	**X**	**IL**			
	Mercury	7439-97-6	**IN,IL,MI,WI**	**IN,IL,MI,MW,GLNPO**	**IL**			
	Methylmercury		**X**					
	Molybdenum	7439-98-7	GLNPO					
	Nickel	7440-02-0	**IN,IL,MI,WI,GLNPO**	**MW**	**IL**			
	Potassium	7440-09-7	**IL,MI,WI,GLNPO**		**IL**			
	Selenium	7782-49-2	**IN**	**MW**	**X**			**X**
	SEM - Silver		**X**				**X**	
	SEM-Cadmium		**X**					
	SEM-Copper		**X**					
	SEM-Lead		**X**					
	SEM-Mercury		**X**					
	SEM-Nickel		**X**					
	SEM-Zinc		**X**					
	Silver	7440-22-4	**IN,IL,GLNPO**	**X**	**IL**			
	Sodium	7440-23-5	IN,IL,Mi, WI,GLNPO					
	Stontium	7440-24-6	IL, GLNPO					
	Thallium	7440-28-0	**GLNPO**		**X**			
	Tin	7440-31-5	**WI, GLNPO**	**MW**	**X**			
	Titanium	7440-32-6	**GLNPO**					
	Zinc	7440-66-6	**IL,IN,MI,WI,GLNPO**	**MW**	**IL**			
Nutrients and Anions								
	Total Inorganic Carbon		**X**		**X**			
	Total Organic Carbon		**GLNPO**		**GLNPO (susp.)**			
	Total carbon		**X**		**X**			
	Dissolved organic carbon		**X**					
	Particulate Carbon		**X**					

	Ammonia mg/L as N		IN,IL,WI					
	Ammonia mg/L as NH4		WI					
	Ammonia plus Organic N	17778-88-0	IL, IN, MI, WI, MW					
	Chloride	16887-00-6	IN,IL,MI,WI, GLNPO					
	Fluoride	16984-48-4	IN, IL, MI					
	Nitrate	14797-65-0	MI					
	Nitrite plus nitrate mg/L as N		IN,IL,MI,WI, GLNPO					
	Nitrate	14797-55-2	MI					
	Nitogen, total (nitrate+nitrite+ammonia+organicN		WI					
	Nitrogen, total		WI		GLNPO			
	Phosphorus	7723-14-0	IN,IL,WI,GLNPO		IL,GLNPO			
	Orthophosphate	14265-44-2	MI, WI					
	Sulfate	14808-79-8	IN, IL, MI					
	Sulfide	18496-25-8	IN					
	Silica	7631-86-9	IN,IL,WI,GLNPO					
	Silicon amorphous powder			MW				
	Total suspended solids		IN					
			X					
Bulk organics								
			X					
Volatile organic compounds (VOCs)								
	1,6,7-Trimethylnaphthalene	2245-38-7	IN	X	X			
	1-Methylphenanthrene	832-69-9		MW	X			
	2,3,5-trimethylnaphthalene	2245-38-7			X			
	2,4-Dinitrophenol	51285	X	X			X	
	2,4-Dinitrotoluene	121142	X	X				
	2,6-dimethylnaphthalene	581-42-0		MW	X			
	2,6-Dinitrotoluene	606202	X					
	2-Methyl-4,6-Dinitrophenol	534521	X	X				

	2-Nitrophenol	88755	**X**					
	3-Chlorophenol	108-43-0	**X**					
	3-Methyl-4-Chlorophenol	59507	**X**					
	4-Nitrophenol	100027	**X**					
	Acenaphthene	83329	**X**	**MW**	**X**			
	Acrolein	107028	**X**	**X**				
	Acrylonitrile	107131	**X**	**X**				
	Azinphos-methyl		**X**					
	Benzidine	92875	**X**	**X**				
	Bis(2-Ethylhexyl) Phthalate	117-81-7	**IN**	**X**				
	Brominated diphenyl ether 154	207122-15-4		**GLNPO**				
	Bromodichloromethane	75-27-4	**IL**					
	Butylbenzyl PhthalateW	85687	**X**					
	Carbon tetrachloride	56235	**X**					
	Decalin			**X**				
	Dibenzo(a,h)Anthracene	53703	**X**	**X**	**X**			
	Dibenzofuran	132-64-9		**MW**	**X**			
	Dibenzothiophene	132-65-0		**MW**	**X**			
	Dichloromethane	75-09-2	**IL**					
	Diethyl PhthalateW	84662	**X**	**X**				
	Dimethyl PhthalateW	131113	**X**	**X**				
	Di-n-Butyl PhthalateW	84742	**X**	**X**				
	Dinitrophenols	none	**X**	**X**				
	Di-n-Octyl Phthalate	117840	**X**					
	Ethylbenzene	100414	**IL, MI**	**X**				
	Ideno(1,2,3-cd)Pyrene	193-39-5	**X**					
	Methylmercury	22967-92-6	**X**					
	Nitrobenzene	98953	**X**					
	Nitrosamines	various	**X**					
	N-Nitrosodi-n-butylamine (Nitrosodibutylamine, N)	924-16-3	**X**					
	N-Nitrosodiethylamine	55-18-5	**X**					

	(Nitrosodiethylamine, N)							
	N-Nitrosopyrrolidine (Nitrosopyrrolidine, N)	930-55-2	X					
	N-Nitrosodimethylamine (NDMA) (N-Nitrosodimethylamine)	62759	X					
	N-Nitrosodi-n-propylamine (NDPA) (N-Nitrosodi-n-Propylamine)	621-64-7	X	X				
	N-Nitrosodiphenylamine	86306	X					
	nonylphenol	25154-52-3	X					
	Pentachloroanisole	1825-21-4		MW				
	Pentachlorobenzene	608-93-5	X	MW,GLNPO	X			
	phenol	108952	X	X				
	phenolic compounds		IL					
	1,2,4,5-Tetrachlorobenzene	95-94-3	X					
	Tetrachloromethane	56-23-5	IL					
	Toluene	108-88-3	IL, MI					
	Toxaphene	8001352	X					
	Dibutyltin	1002-53-5		MW				
	Tribromomethane	75-25-2	IL					
	Trichloroethylene	79-01-6	IL	X				
	Trichloromethane	67-66-3	IL					
	Vinyl chloride	75014	X	X				
	Xylene	1330-20-7	IL, MI					
Pesticides								
	2,4'-DDD or o_p'-DDD	53-19-0		MI, MW,GLNPO	X			
	2,4'-DDE	3424-82-6	IN	IL,MI,GLNPO	X			
	2,4'-DDT or o,p'-DDT	50-29-3	IN,MI	MI, MW,GLNPO	X	IADN		X
	4,4'-DDD or p_p'-DDD	72-54-8	X	MI, MW,GLNPO	X	IADN		
	4,4'-DDE or p_p'-DDE	72559	X	MI,MW,GLNPO	X	IADN		
	4,4'-DDT or p,p'-DDT	72548	X	X	X	X		
	Total DDT			GLNPO				
	Acetochlor	34256-82-1	IN					

	Alachlor	15972-60-8	IN					
	trans-Nonachlor	39765-80-5	IN	MI	X	IADN		X
	Atrazine		IN					
	Aldrin	309-00-2	IN	IL,MI,MW,GLNPO	X	IADN	X	
	alpha-chlordane			MW				
	beta.-Endosulfan (Endosulfan II)	33213-65-9	X	MW	X	IADN		X
	Bifenthrin	82657-04-3	X					
	Butyltins, total			MW				
	Chlordane	57-74-9	MI	MI,MW				
	Chlordane (technical)	12789-03-6	IN					
	Chlorpyrifos	2921-88-2	IN	MW				
	cis-Chlordane	5103-71-9	IN	IL, GLNPO		IADN		
	cis-Nonachlor	5103-73-1	IN	MI,MW,GLNPO				
	Cyanazine	21725-46-2	IN					
	Cyanide?	57-12-5	IN,IL,MI	X				
	Dacthal_monoacid	887-54-7	X					
	.delta.-Hexachlorocyclohexane	319868	X	X	X			
	Demeton	8065-48-3	X					
	Diazinon	333-41-5	X					
	Dieldrin	60-57-1	IN,IL	MI,MW,GLNPO	IL	IADN		
	alpha-endosulfan	959-98-8		MW		IADN		
	Endosulfan sulfate	1031-07-8	X	MW	X			
	Endrin	72-20-8	IN	IL,MW,GLNPO	X	IADN		
	Endrin Aldehyde	7421934	X	X				
	gamma-Chlordane	5566-34-7		MI, MW, GLNPO		IADN		
	Heptachlor	76-44-8	IN,IL	IN,IL,MI,MW,GLNPO	X			
	Heptachlor-Epoxide	1024-57-3	IN, IL	IL, GLNPO	X	IADN		
	Hexachlorobenzene	118-74-1	IN, IL, MI	MI, MW, GLNPO	X	IADN		
	Lindane (gamma-BHC)	58-89-9	IN,IL,MI	IL,MI,MW,GLNPO	IL	IADN		
	Malathion	121-75-5	X					
	p_p'-Methoxychlor	72-43-5	IN,IL	IL	IL	IADN		

	Methyl Bromide	74-83-9	X					
	Chloromethane (Methyl Chloride)	74-87-3	X					
	Metolachlor	51218-45-2	IN					
	Metolachlor_oxanilic_acid							
	Mirex	2385-85-5	X	IL, MI, MW, GLNPO	X	X		X
	Monobutyltin	78763-54-9		X	X			
	Oxychlordane	27304-13-8	IN	MI, MW, GLNPO		IADN		
	Parathion		X					
	Pendimethalin	40487-21-1	IN					
	Propachlor	1918-16-7	IN					
	Simazine		IN					
	Terbufos		IN					
	Tetrabutyl tin			MW				
	Toxaphene	8001-35-2	IL,MI	IL,MI,GLNPO				
	trans-Chlordane	5103-74-2	IL	IL,GLNPO		X		
	Triazine screen		WI					
	Tribenuron-methyl	101200-48-0?	X					
	Tributyltin	56573-85-4	X	MW	X			
	Trifluralin	1582-09-08	IN					
Halogenated hydrocarbons								
	1,1,1,2-Tetrachloroethane		X					
	1,1,1-Trichloroethane	71-55-6	IL					
	1,1,2,2-Tetrachloroethane	79345	X	X				
	1,1,2-Trichloroethane	79005	X	X				
	1,1-Dichloroethane	75-34-3	IL					
	1,1-Dichloroethylene	75-35-4	IL	X				
	1,2,3,4-Tetrachlorobenzene	95-94-3		MW	X			
	1,2,4-Trichlorobenzene	120821	X					
	1,2-Dichlorobenzene	95-50-1	X					
	1,2-Dichloroethane	107-06-2	IL					

	1,2-Dichloropropane	78-87-5	X	X				
	1,3-Dichloropropane	142-28-9	IL					
	1,2-Diphenylhydrazine	122667	X	X				
	1,2-Cis-Dichloroethene	156-59-2	IL					
	1,2-Trans-Dichloroethylene	156-60-5	IL	X				
	1,3-Dichlorobenzene	541731	X	X				
	1,3-Dichloropropene	542756	X	X				
	1,4-Dichlorobenzene	106-46-7	IL, MI	X				
	2,3,4,6-Tetrachlorophenol		X					
	2,3,7,8-TCDD	1746016	X	X				
	2,3-Dichlorophenol		X					
	2,4,6-Trichlorophenol	88-06-2	X	X				
	2,4-Dichlorophenol			X				
	2,4-Dimethylphenol	105-67-9	X	X				
	2,5-Dichlorophenol		X					
	2,6-Dichlorophenol		X					
	2-Chloroethylvinyl Ether	110758	X					
	2-Chloronaphthalene	91587	X	X				
	2-Chlorophenol	95-57-8	X					
	3,3'-Dichlorobenzidine	91941	X	X				
	3,4-Dichlorophenol	120832	X					
	4-Bromophenyl Phenyl Ether	101553	X					
	Bromodiphenylether 47	5436-43-1		GLNPO				
	Bromodiphenylether 66	187084-61-5		GLNPO				
	Bromodiphenylether 99	60348-60-9		GLNPO				
	Bromodiphenylether 100	189084-64-8		GLNPO				
	Bromodiphenylether 153	68631-49-2		GLNPO				
	4-Chlorophenol		X					
	4-Chlorophenyl Phenyl Ether	7005723	X					
	Alpha-Hexachlorocyclohexane (alpha-HCH)	319-84-6		MW, GLNPO	X	IADN		

	.beta.-Hexachlorocyclohexane (beta-HCA)	319-85-7	**X**	**MW**	**x**	IADN		
	delta-Hexachlorocyclohexane (delta-HCH)			**MW**				
	Bis(2-Chloroethoxy) Methane	111911	**X**					
	Bis(2-Chloroethyl) Ether	111444	**X**	**X**				
	Bis(2-Chloroisopropyl) Ether	108601	**X**	**X**				
	Bromoform	75252	**X**	**X**				
	Chloroethane	75003	**X**					
	Chloroform	67-66-3	**X**					
	Chlorophenoxy Herbicide (2,4,5,-TP)		**X**	**X**				
	Chlorophenoxy Herbicide (2,4-D)		**X**					
	~~Chloropyrifos~~							
	delta-BHC		**X**					
	Dichlorobromomethane	75274	**X**	**X**				
	Isophorone	78591	**X**					
	Methylene Chloride	75092	**X**	**X**				
	Octachlorostyrene	29082-74-4		**MI, GLNPO**				
	PCB52			**X**	**X**			
	Pentachloronitrobenzene	82-68-8? 2593-15-9?		**X**				
	Pentachlorophenol	87-86-5	**IN**	**X**				
	Polychlorinated Biphenyls (PCBs)	The class is listed	**IL, MI**	**IN,IL,MI,WI,GLNPO,MW**	**X**			
	Tetrachloroethylene	127-18-4	**IL**					
	Polybrominated Biphenyls (PBBs), esp. hexaBB	67774-32-7	**IN**	**MI**				
Polycyclic aromatic hydrocarbons (PAHs)								
	1-methylnaphthalene	90-12-0		**MW**	**X**			
	2-Methylanthracene				**x**			
	2-methylnaphthalene			**X**	**X**			
	3,6-dimethylphenanthrene							
	9,10-dimethylanthracene				**X**			
	9-methylanthracene				**X**			

	Acenaphthylene	208-96-8		**MW**	**X**			
	Anthracene	120-12-7	**MI**	**X**	**X**	IADN		
	Benz[a]anthracene	56553		**X**	**X**			
	Benzene	71-43-2	**IL, MI**					
	Benzo[a]anthracene	56553		**MW**	**X**	IADN		
	benzo[a]pyrene	50-32-8	**IN,MI**	**MW**	**X**	IADN		
	Benzo[b]fluoranthene	205992	**X**	**IN?, MW**	**X**	IADN		
	Benzo[e]pyrene			**MW**	**X**	IADN		
	Benzo[g,h,i]perylene	191242	**X**	**X**	**X**	IADN		
	Benzo[k]fluoranthene	207-08-9		**X**	**X**	**IADN**		
	Biphenyl	92-52-4		**MW**	**X**			
	Coronene	191-07-1				IADN		
	C1-Decalin			**X**				
	C1-Dibenzothiophenes			**X**	**X**			
	C2-Benzothiophene			**X**				
	C2-Decalin			**X**	**X**			
	C2-Dibenzo(a,h)anthracene	53-70-3		**MW**		IADN		
	C2-Dibenzothiophenes			**MW**	**X**			
	C3-Decalin			**X**	**X**			
	C4-Decalin			**X**	**X**			
	C1-benzo(a)anthracenes /chrysenes				**X**			
	C1-Benzothiophene			**X**				
	C1-Chrysenes	218-01-9 (chrysene)		**MW**	**X**	IADN w/ phenylene		
	C1-fluoranthenes/pyrenes			**X**	**X**			
	C1-fluorenes			**MW**	**X**			
	C1-naphthalenes			**MW**	**X**			
	C1-Naphthobenzothiophene			**X**				
	C1-phenanthrenes/anthracenes	phenanthrene 85-01-8		**MW**	**X**			
	C2-benzo(a)anthracenes /chrysenes				**X**			
	C2-Chrysenes			**MW**	**X**			

	C2-fluoranthenes/pyrenes			**MW**	**X**			
	C2-fluorenes			**MW**	**X**			
	C2-naphthalenes			**MW**	**X**			
	C2-Naphthobenzothiophene			**X**				
	C2-phenanthrenes/anthracenes			**MW**	**X**			
	C3-benzo(a)anthracenes /chrysenes				**X**			
	C3-Benzothiophene			**X**				
	C3-Chrysenes			**MW**	**X**			
	C3-Dibenzo(a,h)anthracene			**X**				
	C3-Dibenzothiophenes			**MW**	**X**			
	C3-Fluoranthenes/Pyrenes			**X**	**X**			
	C3-fluorenes			**MW**	**X**			
	C3-naphthalenes			**MW**	**X**			
	C3-Naphthobenzothiophene			**X**	**X**			
	C3-phenanthrenes/anthracenes			**MW**	**X**			
	C4-benzo(a)anthracenes /chrysenes				**X**			
	C4-Chrysenes			**MW**	**X**			
	C4-naphthalenes			**MW**	**X**			
	C4-phenanthrenes/anthracenes			**MW**	**X**			
	Chlorobenzene	108-90-7	**IL**	**X**				
	Chlorodibromomethane	124-48-1	**IL**	**X**				
	Chrysene	218019			**X**			
	Dibenz(a,c)anthracene							
	Fluoranthene	206-44-0	**MI**	**MW**	**X**	**IADN**		
	fluoranthene, d10							
	Fluorene	86-73-7	**X**	**MW**	**X**	IADN		
	Hexachlorobutadiene	87683	**X**					
	Hexachlorocyclopentadiene	77474	**IN, MI**					
	Hexachloroethane	67721						
	Hexachlorocyclo-hexane-Technical			**X**				
	Indeno[1,2,3-c,d]pyrene	193395	**MI**	**MW**	**X**	**IADN**		

	Naphthalene	91-20-3	**X**	**MW**	**X**			
	Naphthobenzothiophene			**X**				
	Perylene			**MW**	**X**			
	Phenanthrene	85018	**X**	**X**	**X**	**X**		
	Pyrene	129-00-0	**MI**	**MW**	**X**	**IADN**		
	Retene	483-65-8				IADN		
	Total PAHs			**MW**		IADN		

References

Albert, Dennis. (2005). *The Impacts of Various Types of Vegetation Removal on Great Lakes Coastal Wetlands of Saginaw Bay and Grand Traverse Bay*. A report from the Michigan Natural Features Inventory for the Michigan Department of Environmental Quality.

Great Lakes Observing System (GLOS), Regional Coastal Ocean Observing System (RCOOS) Conceptual Plan 2008 – 2017 (Draft, December 2007).

Government of Canada and U.S. EPA Great Lakes National Program Office, 1995. *The Great Lakes Environmental Atlas and Resource Book*. Third Edition.

Public Sector Consultants, 2001. *Michigan Land Resource Project*. Prepared for Michigan Economic and Environmental Roundtable.

United States General Accounting Office Report to Congressional Requestors, April 2003. GREAT LAKES: An Overall Strategy and Indicators for Measuring Progress Are Needed to Better Achieve Restoration Goals, 90 pp. GAO-03-515. Available online at www.gao.gov/cgi-bin/getrpt?GAO-03-515)

U.S. EPA Great Lakes National Program Office, 2006. *Lake Michigan Lakewide Management Plan 2006*.

U.S. EPA Wetlands Division, Office of Wetlands, Oceans and Watersheds, 2006. *Application of Elements of a State Water Quality and Assessment Program for Wetlands*.

Uzarski, Donald G., Thomas Burton, Keto Gyekis, Matthew Cooper, Rebecca Kolar and Jamie Zbytowski, 2005. *The Effects of Coastal Wetland Fragmentation on Fish and Invertebrate Communities.* A Combined Report to the Michigan Department of Environmental Quality from Grand Valley State University and Michigan State University.